6 RECOVERY STRATEGY

The Lake Ozette sockeye salmon ESU is unique among all other ESA-listed salmon ESUs, in that the entire ESU is contained within a single watershed, the Lake Ozette watershed, and, further, the ESU contains only one population, making the population and ESU viability criteria the same. There are relatively few individual landowners and a low human population density throughout the watershed, which remains relatively undeveloped compared to other watersheds closer to the metropolitan areas of Puget Sound. The Lake Ozette watershed has an unusual potential for protection and restoration of landscape processes to support long-term salmon survival.

Habitat, harvest, and hatchery factors affecting Lake Ozette sockeye are included in the recovery strategy. Hatchery and harvest management issues are presented and addressed within the context of biological processes. The strategy used in this recovery plan focuses on the concepts presented in several salmonid habitat recovery planning documents and scientific studies (e.g., Beechie and Boulton 1999; Roni et al. 2002; Beechie et al. 2003; Roni et al. 2005; Stanley et al. 2005). Several scientific studies have illustrated that habitat conditions and aquatic ecosystem function are a result of the interaction between watershed controls, watershed processes, and land use. Scientists and resource managers have recognized that restoration planning that carefully integrates watershed or ecosystem processes is more likely to be successful at restoring depleted salmonid populations (Beechie et al. 2003). The following recovery strategy is based on the relationship between landscape processes and land use, the resulting habitat conditions, and the biological response.

The Lake Ozette sockeye comprehensive recovery strategy uses a multi-parameter approach to develop specific, process-based goals and strategies for each landscape and/or biological process that is linked to a specific limiting factor hypothesis. Section 6.1 describes the framework used to develop process and habitat condition-specific recovery goals and strategies. Sections 6.2 through 6.4 present the goals and strategies used to develop the recovery actions identified in Chapter 7.

The following recovery strategies provide a framework for the proposed recovery program actions described in Chapter 7. The voluntary proposed recovery actions used to implement these strategies will be carried out by the agencies, entities, landowners, and others that have authority and resources to implement recovery actions. This recovery plan is non-regulatory. It does not supplant or override any existing authorities or permitting processes. All future actions will need to be implemented in cooperation with all appropriate permitting authorities and in the context of existing permits, regulations, agreements and public processes.

6.1 STRUCTURE USED IN RECOVERY GOAL AND STRATEGY DEVELOPMENT

The Lake Ozette sockeye recovery strategy framework contains three key elements:

1. Recovery strategies are based upon protection, restoration, and/or rehabilitation of critical processes, inputs, and habitat conditions associated with *identified* limiting factors affecting Lake Ozette sockeye.
2. Recovery strategies are based upon three hierarchical recovery flow charts that integrate geography, sockeye life history, and subpopulations. In these recovery flow charts, all recovery strategies and actions fall within a hierarchical pyramid containing tiers that can be used to sequence and aid in prioritization of strategies and actions needed to restore processes, inputs, and/or conditions affecting sockeye subpopulations.
3. Recovery strategies across the watershed can be categorized by importance based upon subbasin prioritization; priorities are based, in turn, on the spatial extent of sockeye habitat utilization and critical habitat designation, sockeye spawning distribution goals, inter-species competition and hybridization concerns, proximity to key sockeye salmon habitats, and hydrologic influence on Lake Ozette.

Development of recovery goals and strategies incorporated the results of the LFA and hypotheses presented in Chapter 4. The limiting factors figures presented in the introductions to Sections 4.2, 4.3, and 4.4 were simplified into Figure 6.1. The relative mortalities depicted in Figure 6.1 were used as the initial inputs to develop the recovery strategies presented in Sections 6.2 through 6.4. The status of landscape processes and inputs, biological processes, and habitat conditions was then evaluated and incorporated into the development of three independent recovery flow charts (see Sections 6.2, 6.3, and 6.4). Based on these recovery planning flow charts, a hierarchical approach to recovery planning strategies and actions was developed specifically for Lake Ozette sockeye recovery. Finally, a system of subbasin prioritization was developed to determine which subbasins had the most significant influences on watershed processes driving habitat conditions and limiting factors affecting Lake Ozette sockeye. These recovery planning elements are integrated in Chapter 9, where recovery actions and strategies are prioritized and an implementation schedule is presented.

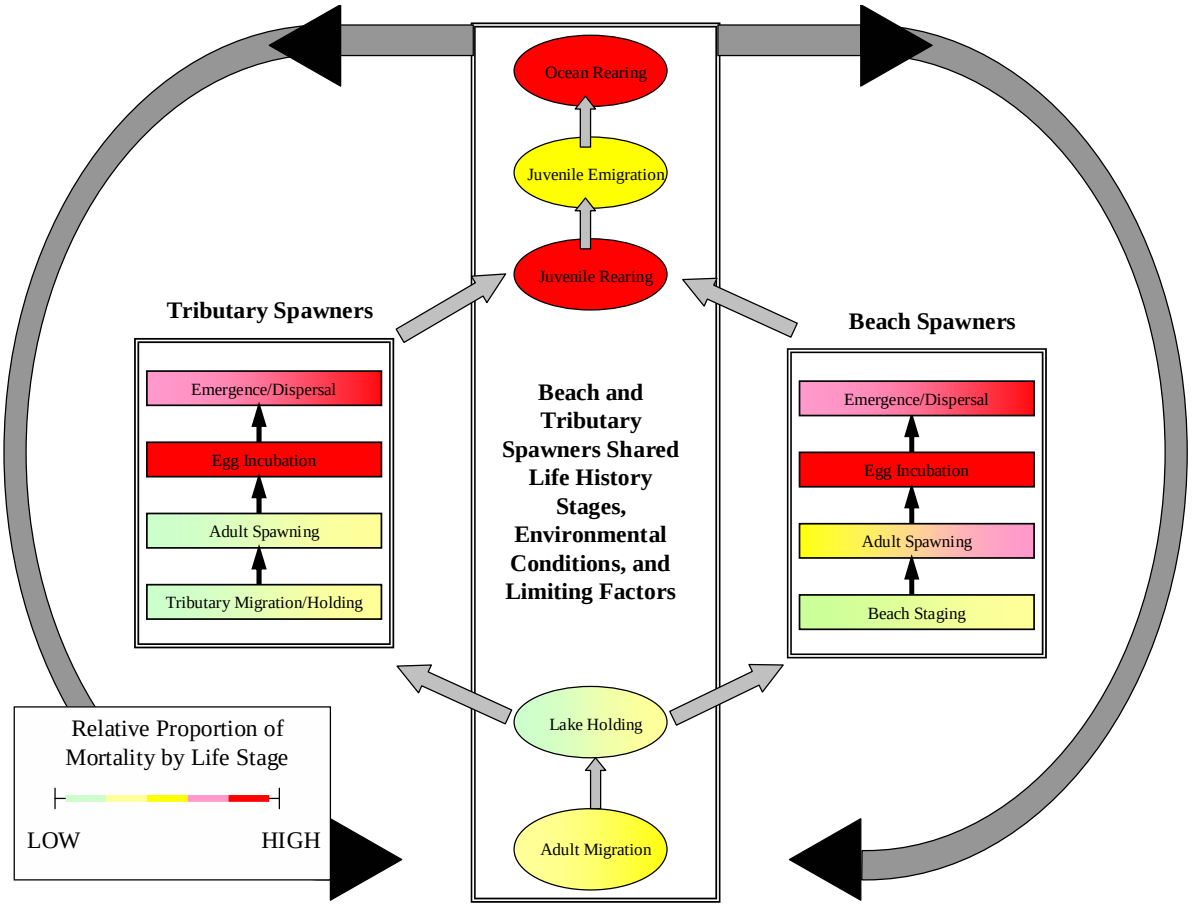

Figure 6.1. Schematic diagram depicting the relative proportion of sockeye mortality by life stage.

6.1.1 Landscape Processes and Inputs, Biological Processes, and Habitat Conditions

As described above, several scientific studies have shown that habitat conditions and aquatic ecosystem function are the result of the interaction between watershed controls, watershed processes, and land use. Recovery plans and strategies that incorporate watershed processes and/or ecosystem recovery are more likely to result in the recovery of degraded habitat conditions and therefore improve the conditions and factors that limit salmonid populations. The recovery strategies are based on the restoration of critical processes, inputs, and habitat conditions associated with identified limiting factors affecting Lake Ozette sockeye. Figure 6.2 illustrates the basic concept of the interaction between watershed controls, watershed processes, habitat effects, and fish population responses. Ozette-specific diagrams were developed to illustrate the connectivity between watershed controls, watershed processes, limiting factor hypotheses, and activities affecting processes and limiting factor hypotheses (see Figure 6.7, Figure 6.9, and Figure 6.11).

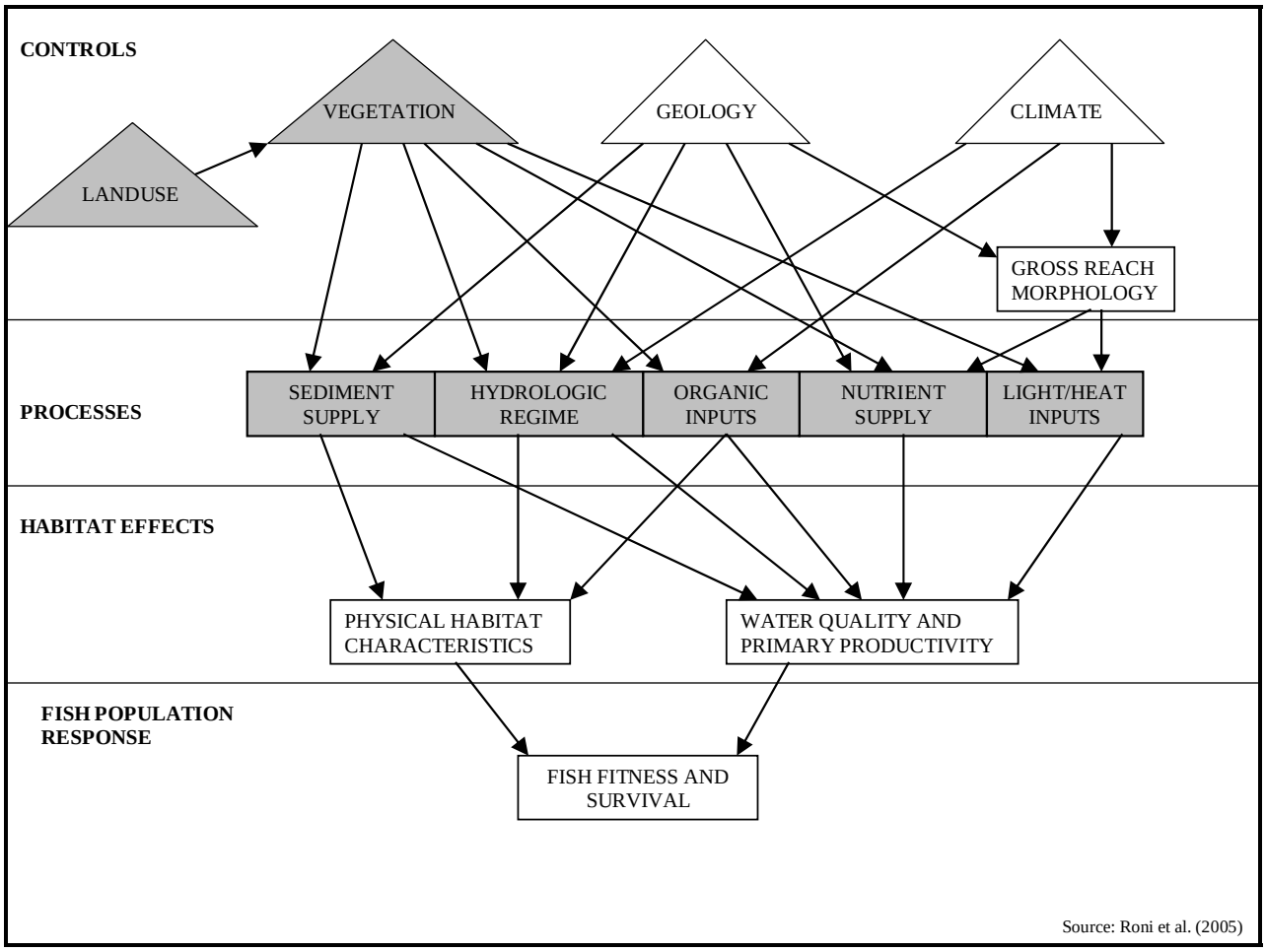

Figure 6.2. Schematic depicting the linkage between landscape controls and land use, habitat-forming processes, habitat conditions, and resulting fish population responses (modified from Roni et al. 2005).

6.1.2 Hierarchical Approach to Sockeye Salmon Population Segment Recovery Strategies

The planning processes started with a general approach to watershed processes and recovery strategy hierarchy developed in the scientific literature by a number watershed scientists. Figure 6.3 contains a flow chart depicting a general hierarchical approach for prioritizing habitat restoration, protection, and enhancement activities with regard to habitat (Roni et al. 2002). This model was then adapted for conditions specific to Lake Ozette and sockeye salmon recovery.

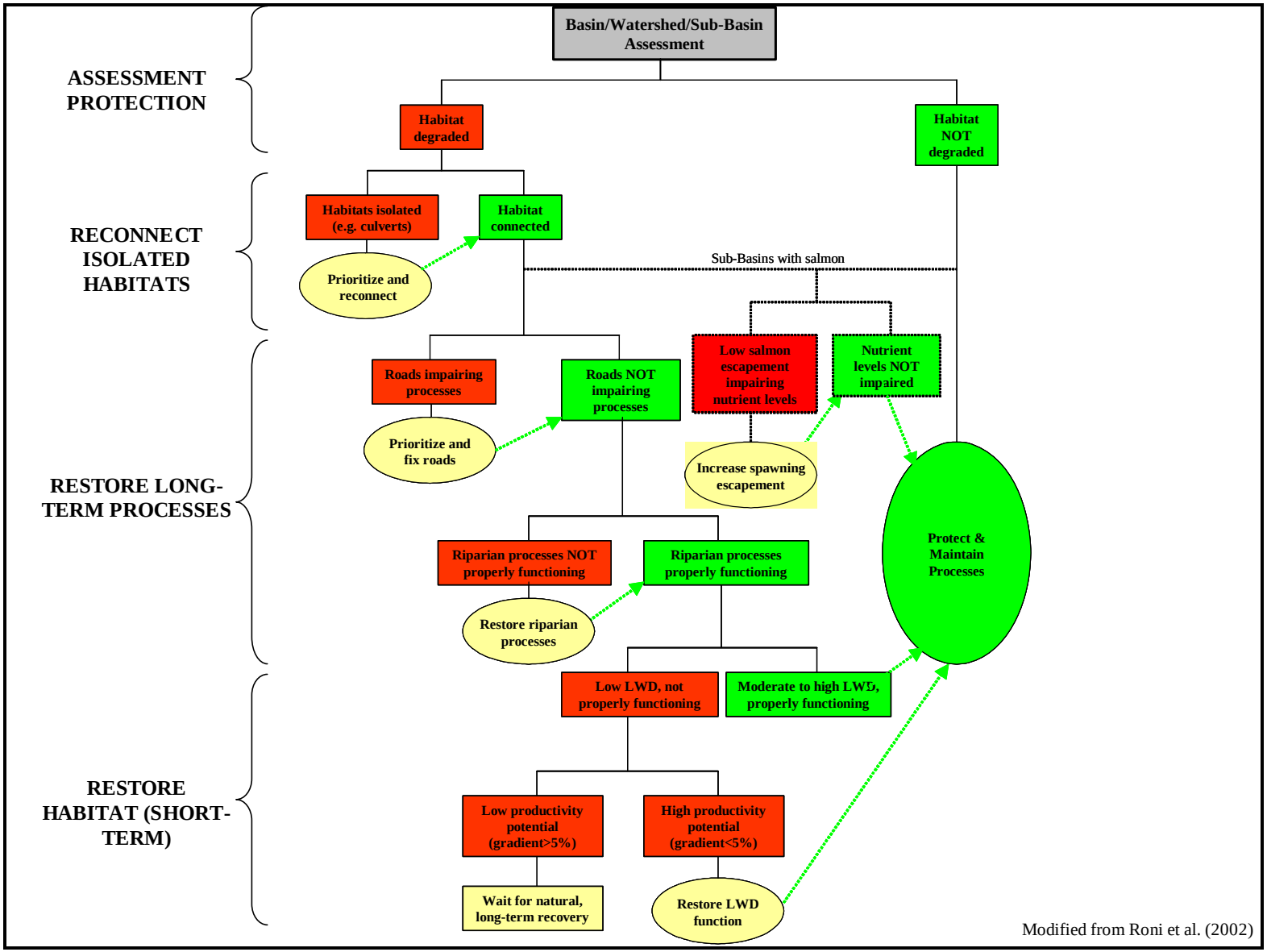

Figure 6.3. Flow chart depicting hierarchical strategy for prioritizing protection, restoration, and enhancement activities. (Note: red rectangles represent impaired processes or conditions, yellow ovals represent the need to develop strategies and implement actions, green rectangles represent restored processes where planners can then move down through the flow chart).

Within the Lake Ozette watershed, some limiting factors, habitat conditions, and life histories are shared among all population segments (subpopulations), while others apply to some segments and not others. As described in previous chapters, subpopulations can be grouped based on similarities of spawning environments (e.g., tributary vs. beach spawning). The recovery goals and strategies presented here are based on geographic, sockeye life history, and subpopulation recovery flow charts for three categories: all population segments, beach spawners only, and tributary spawners only. Ozette-specific flow charts are included in the introductions to Sections 6.2 through 6.4.

These recovery flow charts were used to develop an Ozette sockeye-specific recovery strategy hierarchy (Figure 6.4). All recovery strategies and actions fall within a hierarchal pyramid containing tiers that can be used to sequence and aid in prioritization of strategies and actions needed to restore processes, inputs, and conditions affecting sockeye within each of the three population segments, shown in the corresponding recovery flow charts.

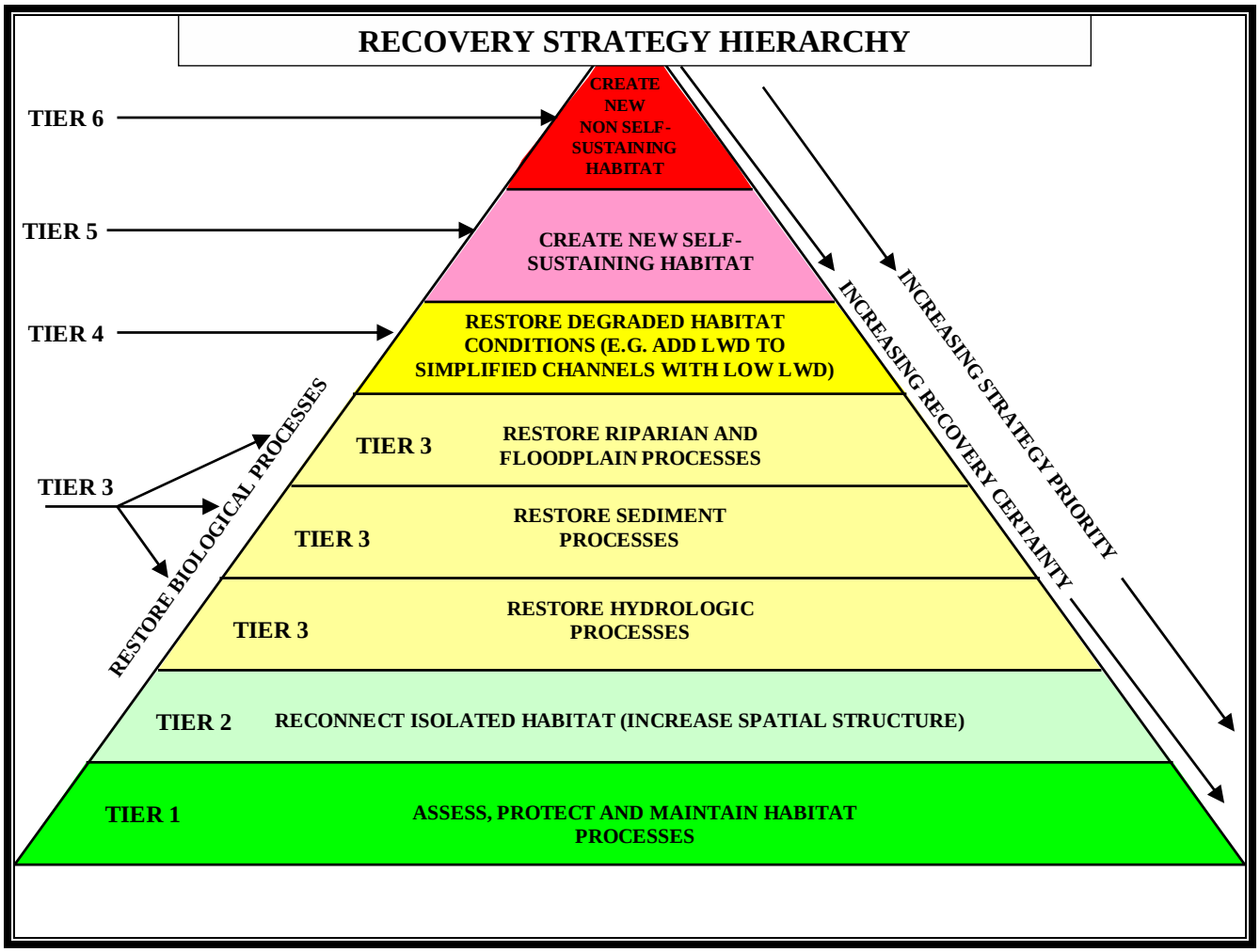

Figure 6.4. Ozette sockeye-specific recovery strategy and action hierarchy.

6.1.3 Subbasin Prioritization Used in Strategy Development

Recovery strategies across the watershed can be ranked according to subbasin priority. Subbasins were prioritized based on the spatial extent of sockeye habitat utilization and critical habitat designation, sockeye spawning distribution goals, inter-species competition (e.g., coho) and inter-species hybridization (with kokanee) concerns, proximity to key sockeye salmon habitats, and hydrologic influence on Lake Ozette. Each subbasin within the Ozette watershed was evaluated based on the flow chart below (Figure 6.5). The following yes-no questions were answered for each subbasin:

- Is the subbasin or stream used by sockeye salmon?
- Is the subbasin or stream, in whole or part, designated critical habitat?
- Is the subbasin or stream system in a location where sockeye spawning is one of the recovery goals (see Appendix B)?
- Is the subbasin or stream system in a location where interspecies competition and/or hybridization are concerns?
- Does the subbasin or stream provide critical habitat to the entire sockeye population at one or more life history stages?
- Is the stream or subbasin confluence located in close proximity to utilized or potential beach spawning habitat?
- Does the subbasin or stream supply 10 percent or more of the lake inflow?

The results of the subbasin prioritization questions are presented in Table 6.1. Figure 6.6 depicts the spatial extent of the subbasin prioritization. All recovery strategies and actions will be evaluated and prioritized at a minimum based upon the limiting factors rating, the hierarchical tier of the strategy or action, and subbasin priority rating (see Section 7.7, Action Integration).

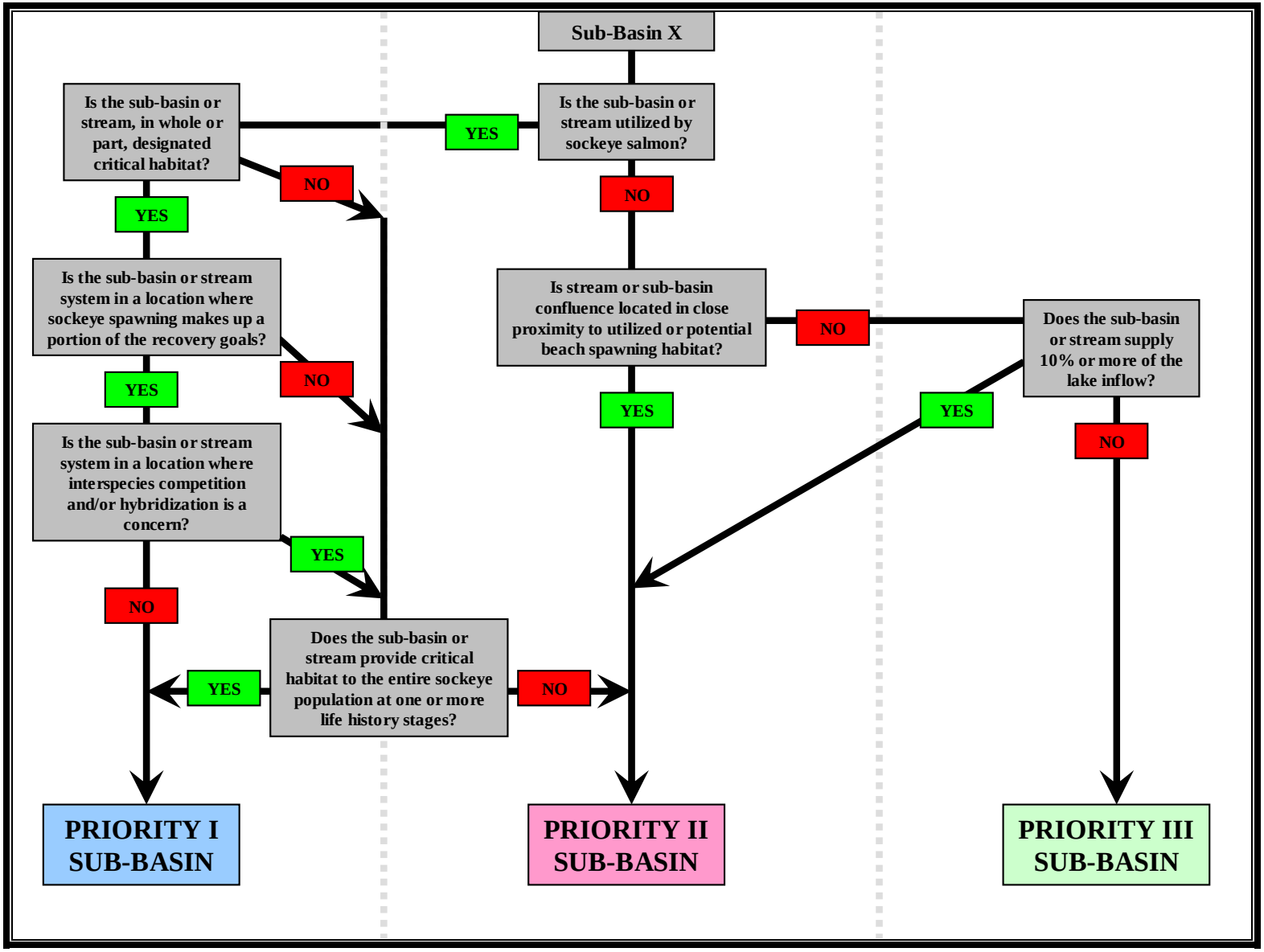

Figure 6.5. Schematic diagram depicting system used for prioritizing Lake Ozette subbasins.

Table 6.1. Responses to subbasin prioritization questions and subsequent subbasin priority ratings.

Subbasin/Stream System	Is the subbasin or stream used by sockeye salmon?	Is the subbasin or stream, in whole or part, designated critical habitat?	Is the subbasin or stream system in a location where sockeye spawning makes up a portion of the recovery goal production?	Is the subbasin or stream system in a location where interspecies competition and/or hybridization is a concern?	Does the subbasin or stream provide critical habitat to the entire sockeye population at one or more life history stages?	Is stream or subbasin confluence located in close proximity to utilized or potential beach spawning habitat?	Does the subbasin or stream supply 10 percent or more of the lake inflow?	Subbasin Prioritization
Lake Ozette	Yes	Yes	Yes	No	Yes	NA	Yes	**Priority I**
Ozette River	Yes	Yes	No	No	Yes	NA	NA	**Priority I**
Umbrella Creek	Yes	Yes	Yes	No	No	Yes	Yes	**Priority I**
Big River	Yes	Yes	Yes	No	No	No	Yes	**Priority I**
Coal Creek	Yes	Yes	No	No	No	No	No	Priority II
Crooked Creek	Yes	Yes	Yes	Yes	No	No	Yes	Priority II
Siwash Creek	No	No	No	Yes	No	Yes	No	Priority II
Elk Creek	No	No	No	Yes	No	Yes	No	Priority II
WRIA# 20.0073	No	No	No	Yes	No	Yes	No	Priority II
WRIA# 20.0078	No	No	No	No	No	Yes	No	Priority II
Unnamed west- and east-side streams	No	No	No	No	No	Yes	No	Priority II
Palmquist Creek	No	No	No	Yes	No	No	No	Priority III
Quinn Creek	No	No	No	Yes	No	No	No	Priority III
South Creek	No	No	No	No	No	No	No	Priority III
Allen Slough	No	No	No	No	No	No	No	Priority III
WRIA# 20.0079	No	No	No	No	No	No	No	Priority III
All other unnamed streams flowing into Lake Ozette or the Ozette River	No	No	No	No	No	No	No	Priority III

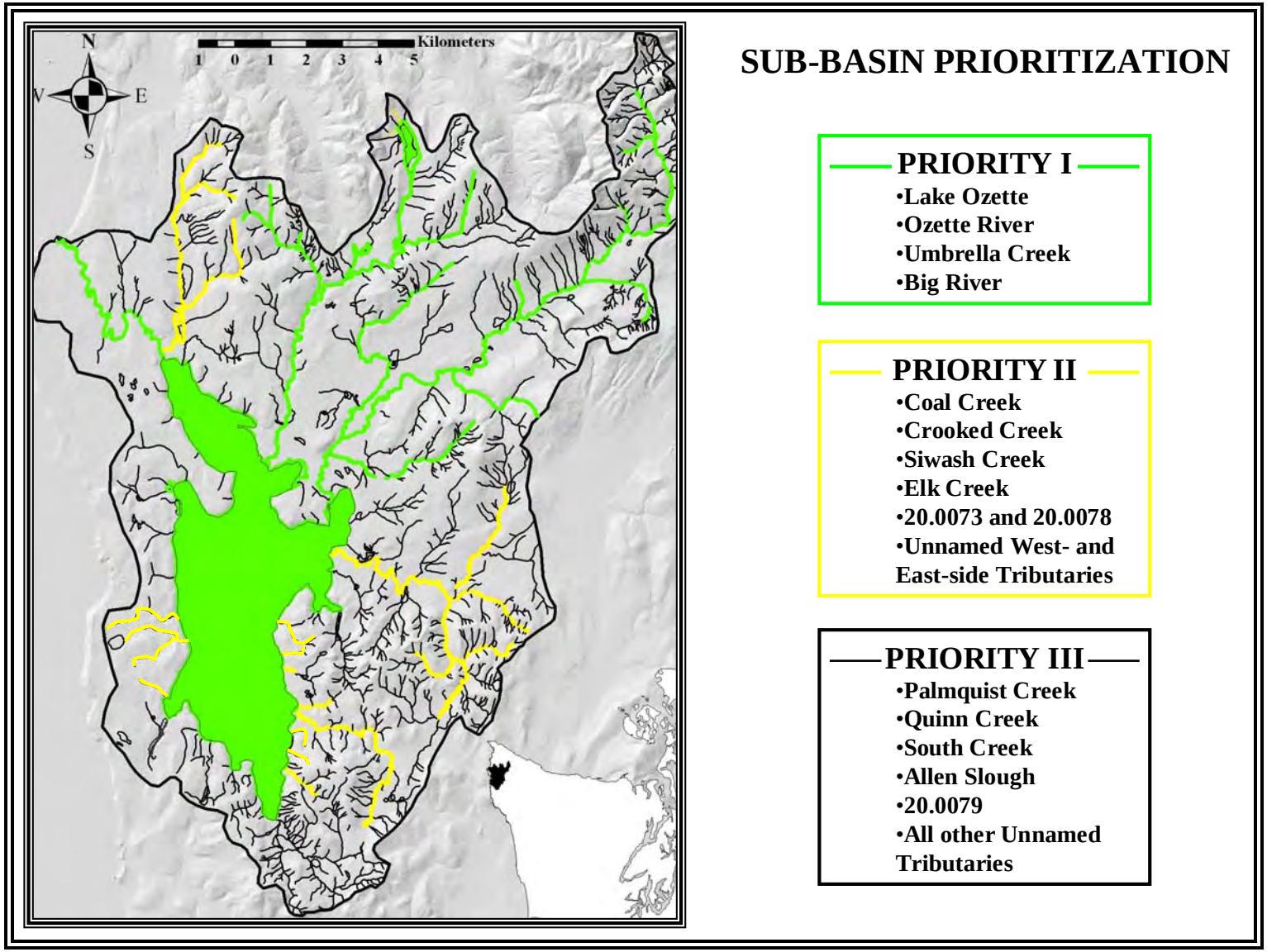

Figure 6.6. Lake Ozette subbasin prioritization. Green lines depict priority I subbasins, yellow lines depict priority II subbasins, and black lines entering Lake Ozette and the Ozette river depict priority III subbasins.

6.2 GOALS AND STRATEGIES TO RESTORE PROCESSES AND CONDITIONS AFFECTING ALL POPULATION SEGMENTS

Section 4.2 identifies and describes limiting factors affecting all population segments. All Lake Ozette sockeye experience the same habitat conditions and limiting factors during five life history stages: adult migration (Ozette River), adult holding (Lake Ozette), juvenile rearing (Lake Ozette), smolt emigration to the ocean (Ozette River), and marine rearing (Pacific Ocean). Each limiting factor was assessed based upon the sockeye life stage affected, the process or input influencing the limiting factors, and activities that affect each process and input. Figure 6.7 illustrates the interconnectedness between processes and limiting factors relative to all population segments. It is important to note how complex and interconnected the processes and limiting factors are, because the following subsections present this information in a highly simplified manner. Figure 6.8 depicts a hierarchical strategy for prioritizing protection, restoration, and enhancement activities for all population segments.

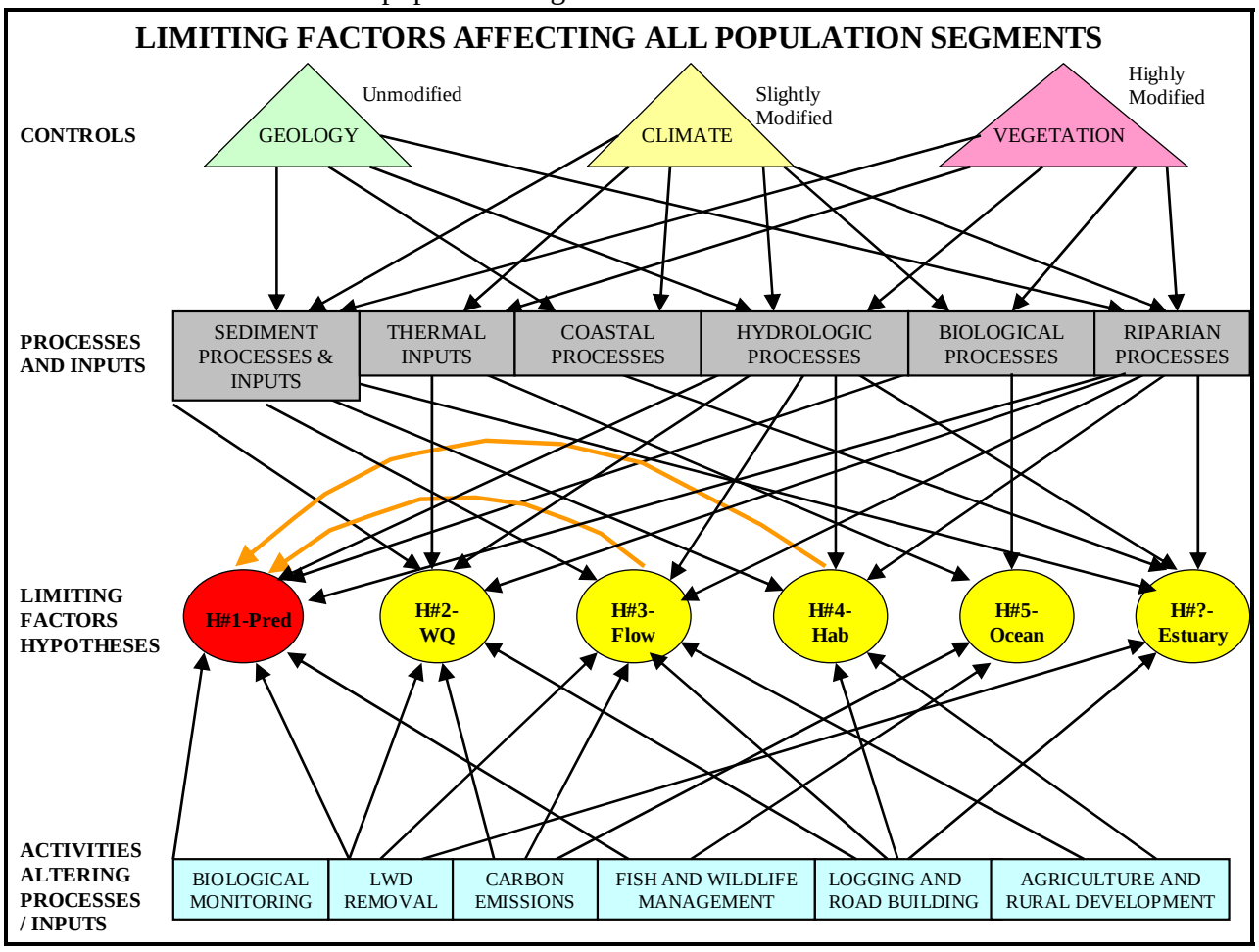

Figure 6.7. Schematic diagram depicting the linkages between watershed controls, watershed-scale processes and inputs, limiting factors hypotheses, and activities that alter processes and inputs.

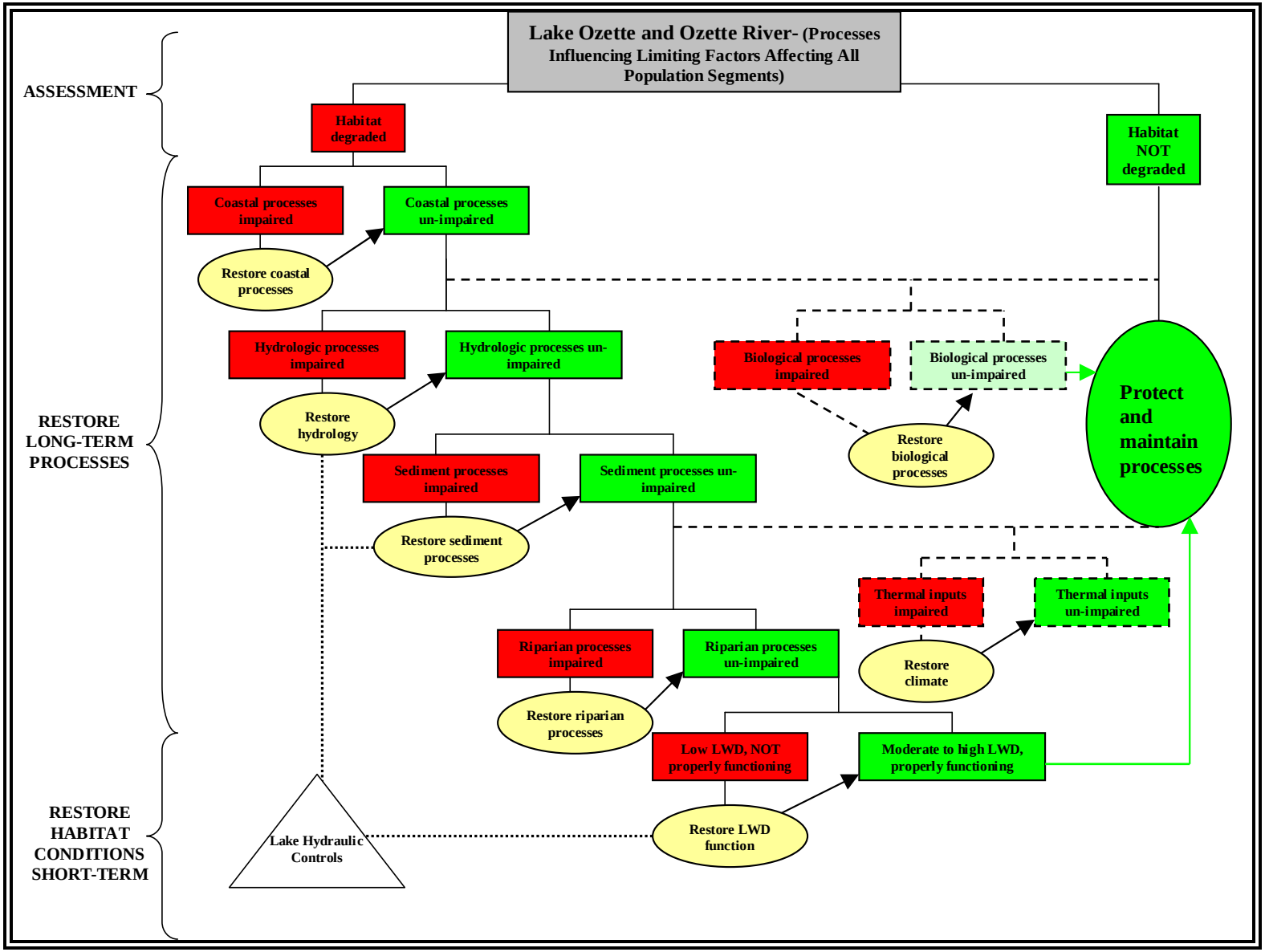

Figure 6.8. Flow chart depicting hierarchical strategy for prioritizing protection, restoration, and enhancement activities for factors affecting all population segments (adapted from Roni et al. 2002).

6.2.1 Coastal Processes

Within the context of this subsection, coastal processes are those processes that deliver and route sediment along the coastal shoreline and act to develop the landforms found near the mouth of the Ozette River, as well as influence physical estuarine conditions. Landscape processes and inputs occurring upstream of the mouth of the Ozette River, along with coastal processes, strongly influence the conditions at the transition from the riverine environment to the marine environment (e.g., the river is currently open and accessible to migrating adults and emigrating juvenile sockeye year-round, and the outlet has never been observed to be bar-bound). Table 6.2 is a summary of the status (impaired/unimpaired) of coastal processes, linkage to limiting factors hypotheses, and activities affecting coastal processes.

Table 6.2. Summary of coastal process condition, linkage to limiting factors hypotheses, and activities affecting coastal processes.

Process/input condition status:	Unimpaired
Primary limiting factor hypothesis Associated with Process/Input:	NA (potential alterations of estuary habitat)
Life history stages affected:	Juvenile emigration, adult migration
Degree of impact of primary limiting factor hypothesis:	Unknown
Secondary limiting factors hypotheses associated with process/input:	NA
Activities and/or conditions affecting process/input:	None identified

Recovery goal: Maintain and protect coastal processes to prevent the development of future limiting factors associated with coastal processes (e.g., loss of estuary habitat, seasonal bar-bound conditions at the mouth of the Ozette River).

Recovery strategy 1: Protect coastal processes and estuary habitat from degradation by implementing ONP, Makah Tribal, and National Marine Sanctuary regulations and management plans. Implement the Coast Guard's Northwest Area Contingency Plan in response to any oil spill within the Sanctuary.
Recovery strategy hierarchy: Tier 1.
Priority subbasin rating: Priority I

6.2.2 Biological Processes (H#1-Pred)

Within the context of this subsection, biological processes are those that occur in Lake Ozette, the Ozette River, and the Pacific Ocean. Limiting factor Hypothesis 1 (Section 4.2.1.1) is the primary limiting factor hypothesis related to biological processes affecting all population segments. Biological processes in fresh water are complex, since many watershed scale processes, habitat conditions, and management activities may affect

biological processes and ultimately the predator-prey balance within the ecosystem. Activities and/or conditions that currently affect predation include: LWD removal and habitat conditions in Ozette River, biological monitoring, and fish and wildlife management. Table 6.3 is a summary of the status (impaired/unimpaired) of biological processes, linkage to limiting factors hypotheses, and activities affecting predation.

Table 6.3 Summary of biological process condition, linkage to limiting factors hypotheses, and activities affecting biological processes.

Process/input condition status:	Impaired
Primary limiting factor hypothesis associated with process/input:	Hypotheses 1 (Pred)
Geographic location of limiting factor:	Lake Ozette, Ozette River
Life history stages affected:	Juvenile rearing, juvenile emigration, adult migration and holding
Degree of impact of primary limiting factor hypothesis:	High Key limiting factor
Secondary limiting factors hypotheses associated with process/input:	Hypothesis 5 (MS)
Activities and/or conditions affecting predation:	LWD removal and habitat conditions in Ozette River, biological monitoring, fish and wildlife management

Recovery goal: Restore and protect biological process so the balance between predators and prey is restored and is no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 2: Implement strategies and actions to increase egg-to-fry survival of beach and tributary spawners so that the habitat can produce abundant sockeye salmon, reducing the overall percent impact of predation on the population.
Recovery strategy hierarchy: Tier 1-4.
Priority subbasin rating: Priority I-III.

Recovery strategy 3: Restore natural predator-prey balance by eliminating non-native fish species.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

Recovery strategy 4: Restore natural predator-prey balance by eliminating and/or strictly limiting fishing-related mortalities on Lake Ozette sockeye.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

Recovery strategy 5: Improve predator avoidance opportunities in the Ozette River (e.g., improved weir and smolt trapping techniques, large wood placement) (see also RS#16).
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

Recovery strategy 6: Implement actions that restore the hydraulic and hydrologic conditions of the Ozette River (e.g., LWD and sediment deposition) to provide favorable flow conditions for sockeye migration and predator avoidance.
Recovery strategy hierarchy: Tier 1-4.
Priority subbasin rating: Priority I.

Recovery strategy 7: Work at local, regional, and international scales to maintain favorable ocean conditions that support sockeye salmon.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

6.2.3 Hydrologic Processes (H#3-Q)

Within the context of this subsection, hydrologic processes are those processes that store, deliver, and route water into the Ozette River. Limiting factor Hypothesis 3 (Section 4.2.2.2) is the primary limiting factor hypothesis related to hydrologic processes affecting all population segments. Ozette River hydrology is largely controlled by: a) climate, b) lake and tributary hydrology, c) sediment input, routing, and storage in the upper half-mile of the Ozette River, and d) LWD recruitment and storage (in logjams) in the upper one mile of the Ozette River. Activities affecting hydrologic processes include: historical LWD removal (affecting lake hydrology), ONP facilities operation and maintenance in Ozette River riparian zone (affecting LWD recruitment and lake hydrology), logging and road building throughout the watershed (affecting tributary hydrology and lake hydrology) and specifically in Coal Creek (affecting sediment processes), agriculture and rural development in the Big River valley (affecting tributary and lake hydrology), and other floodplain alterations in major tributaries to the lake (affecting tributary and lake hydrology). Table 6.4 is a summary of the status (impaired/unimpaired) of hydrologic processes, linkage to limiting factors hypotheses, and activities affecting hydrologic processes.

Table 6.4 Summary of hydrologic process condition, linkage to limiting factors hypotheses, and activities affecting hydrologic processes.

Process/input condition status:	Impaired
Primary limiting factor hypothesis associated with process/input:	Hypothesis 3 (Q)
Geographic location of limiting factor:	Ozette River
Life history stages affected:	Adult migration and juvenile emigration
Degree of impact of primary limiting factor hypothesis:	Unknown Contributing limiting factor
Secondary limiting factors hypotheses associated with process/input:	Hypotheses 1 (Pred), 2 (WQ), 4 (Hab)
Activities and/or conditions affecting process/input:	LWD removal, ONP facilities, logging and road building, agriculture and rural development, and other floodplain alterations

Recovery goal: Restore hydrologic processes and natural hydrologic variability in the Ozette River to the extent that hydrologic influences according to Hypotheses 1, 2, 3, and 4 are no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 8: Quantitatively assess hydrologic impacts from land use and LWD removal activities and develop a distributed hydrologic model calibrated for each tributary in conjunction with Ozette River hydraulic model to prioritize actions needed to improve natural hydrologic functions.
Recovery strategy hierarchy: Tier 1.
Priority subbasin rating: Priority I

Recovery strategy 9: Restore natural hydraulic controls (both LWD and sediment) in the upper one mile of the Ozette River based on guidance from watershed hydrologic modeling.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I.

Recovery strategy 10: Implement hydrologic strategies for sockeye spawning subbasins based on outcome of hydrologic modeling (see Section 6.4.2 recovery strategies).
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

Recovery strategy 11: Based on the results of watershed hydrologic modeling, implement hydrologic strategies to restore Lake Ozette inflow hydrology in priority II and III subbasins.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I, II, and III.

6.2.4 Sediment Processes (H#2-WQ; H#3-Q)

Within the context of this subsection, sediment processes are those processes that store, deliver, and route sediment into the Ozette River. Limiting factor Hypotheses 2 and 3 (Sections 4.2.2.1and 4.2.2.2) are the primary limiting factor hypotheses related to sediment processes affecting all population segments. For the discussion regarding hydrologic impacts of sediment processes, see Section 6.2.3. Water quality conditions in the Ozette River are primarily controlled by sediment inputs (SSC) and thermal inputs (high stream temperatures). For the discussion regarding thermal input-related water quality impacts, see Section 6.2.5. Activities affecting sediment processes include: a) LWD removal or losses in LWD volume, which have caused channel destabilization resulting in increased sediment delivery to the Ozette River; b) logging and road building (in tributaries to the Ozette River), which have increased sediment inputs, reduced sediment storage, and resulted in more frequent SSC events in the Ozette River; c) channel alterations and sediment mobilizing events, which have increased coarse sediment deposition at the confluence of Coal Creek and the Ozette River. Increased

sediment deposition has resulted in an increase in the lake's outlet control elevation, thereby reducing the Ozette River's streamflow (see Hypothesis 3), which results in reduced water quality. Table 6.5 is a summary of the status (impaired/unimpaired) of sediment processes, linkage to limiting factors hypotheses, and activities affecting sediment processes.

Table 6.5 Summary of sediment process condition, linkage to limiting factors hypotheses, and activities affecting sediment processes.

Process/input condition status:	Impaired
Primary limiting factor hypotheses associated with process/input:	Hypotheses 2 (WQ) and 3 (Q)
Geographic location of limiting factor:	Ozette River
Life history stages affected:	Adult migration and juvenile emigration
Degree of impact of primary limiting factor hypothesis:	Moderate[1] Contributing limiting factor
Secondary limiting factors hypotheses associated with process/input:	Hypotheses 1 (Pred), 4 (Hab)
Activities and/or conditions affecting process/input:	LWD removal and losses, logging and road building

[1]Moderate rating is based mainly on temperature impacts; SSC impacts are thought to have a lower overall level of impact on sockeye.

Recovery goals: a) Restore natural sediment production and transport processes in the Ozette River subbasin to the extent that sediment influences on streamflow no longer result in reduced streamflows that may limit Lake Ozette sockeye VSP parameters. b) Restore natural sediment production and transport processes in the Ozette River subbasin so that limiting factors per hypotheses 1, 2, 3, and 4 are no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 12: Within the Coal Creek subbasin, quantitatively assess sediment production impacts from logging (gully creation, landslides), road building, and LWD removal. Develop program to eliminate and/or reduce land use related sediment inputs. Implement sediment reduction program.
Recovery strategy hierarchy: Tier 1/3.
Priority subbasin rating: Priority I, II

Recovery strategy 13: Restore natural hydraulic controls (both LWD and sediment) in the upper one mile of the Ozette River based on guidance from watershed hydrologic modeling.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I.

6.2.5 Thermal Inputs (H#2-WQ; H#3-Q; H#5-MS)

This subsection concerns thermal inputs to the Pacific Ocean, Lake Ozette, and the Ozette River. Limiting factor Hypotheses 2 (Section 4.2.2.1), 3 (Section 4.2.2.2) and 5 (Section 4.2.2.4) are relevant to thermal inputs affecting all population segments.

Lake Ozette is the primary source of high water temperatures in the Ozette River during the sockeye smolt and adult migration periods. The lake naturally has no effective shading, and stream temperatures are naturally warm during spring and summer months. The physical processes that contribute to lake and stream temperature are complex; however, considerable evidence exists to suggest that the primary mechanism that contributes to elevated water temperatures in the Ozette River and Lake Ozette is climate change. As stated in Section 4.2.2.1, during the past 90 years, air temperatures during the adult sockeye migration period are estimated to have increased by 1-2^{o}C, based on climate data from a nearby monitoring station. Air temperature is arguably the most important meteorological variable affecting lake surface temperature, as it is causally involved in all heat exchange processes except the absorption of solar radiation and the emission of long-wave radiation from the lake surface (Kettle et al. 2004). Thus, the increase in average air temperature probably indicates an increase in average lake temperature since historical times.

Other possible sources of higher temperatures, such as lack of riparian vegetation and shading, do not appear to be significant here. Recent-year tributary inputs to the lake may be warmer than in the previous century as a result of watershed changes from forestry and agriculture, but the amount of water going into the lake in summer months of low flow is too small to affect overall lake temperature. Further, riparian conditions are mostly excellent along the Ozette River, yet typically little downstream cooling occurs there. It would be possible to increase shade levels in only one location, where riparian conditions are degraded.

As the lake temperature rises, evaporation increases. Because of the inverse relationship between evaporation and discharge to the Ozette River, a warmer lake also results in lower streamflow, in addition to other factors cumulatively affecting streamflow (Hypothesis 3).

Climate change may also affect biological processes and sockeye survival in the ocean (Hypothesis 5). Limited Lake Ozette sockeye smolt-to-adult survival data currently suggest that marine survival is within the expected range for large, southern latitude sockeye smolts. However, in the future, significant climate change (doubling of atmospheric CO2) has the potential to severely limit the marine distribution of sockeye salmon and ultimately the viability of the species within the southern range. Therefore, activities that produce and emit greenhouse gases at levels capable of influencing global climate are a serious threat to Lake Ozette sockeye. Table 6.6 is a summary of the status (impaired/unimpaired) of thermal input processes, linkage to limiting factors hypotheses, and activities affecting coastal processes.

Table 6.6. Summary of thermal input process condition, linkage to limiting factors hypotheses, and activities affecting thermal inputs.

Process/input condition status:	Impaired
Primary limiting factor hypotheses associated with process/input:	Hypothesis 2 (WQ)
Geographic location of limiting factor:	Lake Ozette, Ozette River
Life history stages affected:	Adult migration and juvenile emigration
Degree of impact of primary limiting factor hypothesis:	Moderate[1] Contributing limiting factor
Secondary limiting factors hypotheses associated with process/input:	Hypothesis 5 (MS)
Activities and/or conditions affecting process/input:	Greenhouse gas emissions/climate change

[1]Moderate rating is based mainly on temperature impacts.

Recovery goals: a) Restore and protect thermal input processes in Lake Ozette and the Ozette River to the extent that water temperatures are not further elevated due to changes in climate; b) restore and protect global climate from changes that adversely influence sockeye distribution and survival in the Pacific Ocean.

Recovery strategy 14: Stop or significantly slow climate change by developing and participating in local, regional, national, and global atmospheric anti-pollution programs to reduce emissions of greenhouse gases. In addition, develop a comprehensive mitigation plan to improve the capacity for Lake Ozette sockeye salmon to survive in a warming climate.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I

Recovery strategy 15: Protect Ozette River riparian corridor and reestablish riparian forest where degraded conditions exist.
Recovery strategy hierarchy: Tier 1/3.
Priority subbasin rating: Priority I/III.

6.2.6 Riparian-Floodplain Processes

Within the context of this subsection, riparian and floodplain processes are limited in geographic scope to the Ozette River. Since riparian conditions are excellent throughout most of the Ozette River, riparian processes have no primary linkage to any of the limiting factor hypotheses. However, degraded riparian conditions do exist near the lake's outlet. These degraded conditions influence the rate of recovery of limiting factors described in Hypotheses 1, 3, and 4. The primary activity that contributes to degraded riparian conditions, where they exist, is the development and maintenance of ONP facilities. Floodplain processes are likely affected by the reduced number, size, and quality of logjams in the Ozette River; reducing the frequency and duration of floodplain

inundation. However, floodplain processes are unlikely to affect sockeye during their emigration and migration in the Ozette River because of the timing of sockeye presence relative to streamflows required to activate floodplains and floodplain habitats where they exist. Table 6.7 is a summary of the status (impaired/unimpaired) of thermal input processes, linkage to limiting factors hypotheses, and activities affecting coastal processes.

Table 6.7 Summary of sediment process condition, linkage to limiting factors hypotheses, and activities affecting sediment processes.

Process/input condition status:	Impaired (slightly)
Primary limiting factor hypotheses associated with process/input:	NA
Geographic location of limiting factor:	Ozette River
Life history stages affected:	Adult migration and juvenile emigration
Degree of impact of primary limiting factor hypothesis:	NA
Secondary limiting factors hypotheses associated with process/input:	Hypotheses 1 (Pred), 3 (Q), and 4 (Hab)
Activities and/or conditions affecting process/input:	Development and maintenance of ONP facilities

Recovery goals: Restore, maintain and protect riparian/floodplain processes to the extent that riparian-floodplain influences on limiting factors hypotheses 1, 3, and 4 are no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 15: Protect Ozette River riparian corridor and reestablish riparian forest where degraded conditions exist.
Recovery strategy hierarchy: Tier 1/3.
Priority subbasin rating: Priority I/III.

6.2.7 Habitat Conditions (H#4-Hab)

Within the context of this subsection, habitat conditions are limited in geographic scope to the Ozette River. Limiting factor Hypothesis 4 (Section 4.2.2.3) is the primary limiting factor hypothesis related to habitat conditions affecting all population segments. Ozette River habitat conditions are controlled by: a) climate, b) lake and tributary hydrology, c) sediment input, routing, and storage in the upper Ozette River, d) LWD, and e) floodplain connectivity. Activities affecting habitat conditions include: historical LWD removal, ONP facilities operation and maintenance in Ozette River riparian zone (affecting LWD recruitment), logging and road building in the Ozette River subbasin (affecting sediment processes) and specifically in Coal Creek (affecting sediment processes). Table 6.8 is a summary of the status (impaired/unimpaired) of habitat conditions, linkage to limiting factors hypotheses, and activities affecting habitat conditions.

Table 6.8 Summary of habitat conditions, linkage to limiting factors hypotheses, and activities affecting habitat conditions.

Process/input condition status:	Impaired (slightly)
Primary limiting factor hypotheses associated with process/input:	Hypothesis 4 (Hab)
Geographic location of limiting factor:	Ozette River
life history stages affected:	Adult migration and juvenile emigration
Degree of impact of primary limiting factor hypothesis:	Low Contributing limiting factor
Secondary limiting factors hypotheses associated with process/input:	Hypotheses 1 (Pred) and 3 (Q)
Activities and/or conditions affecting process/input:	Historical LWD removal, ONP facilities operation and maintenance in Ozette River riparian zone, past logging and road building in the Ozette River subbasin

Recovery goals: Restore LWD habitat conditions in the Ozette River to the extent that habitat influences on limiting factors hypotheses 1, 3, and 4 are no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 16: Use large wood placement techniques to restore LWD habitat conditions in the lower 4 miles of the Ozette River. Re-establishment of large wood structures in the lower reaches of Ozette River should focus on improving conditions for avoidance of pinniped predation and adult migration success.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I.

6.3 GOALS AND STRATEGIES TO RESTORE PROCESSES AND CONDITIONS AFFECTING BEACH SPAWNERS

Section 4.3 identifies and describes limiting factors affecting only beach spawners. All beach spawning sockeye experience similar habitat conditions and limiting factors during four life history stages: adult staging (Lake Ozette beaches), adult spawning (beaches), egg incubation (beaches), and emergence and dispersal (beaches). Each limiting factor was assessed based upon the sockeye life stage affected, the process or input influencing the limiting factors, and activities that affect each process and input. Figure 6.9 illustrates the interconnectedness between different processes and limiting factors relative to the beach spawning population segment. It is important to note how complex and interconnected the processes and limiting factors are, because the following subsections present this information in a highly simplified manner. Figure 6.10 depicts a hierarchical strategy for prioritizing protection, restoration, and enhancement activities for beach spawning sockeye.

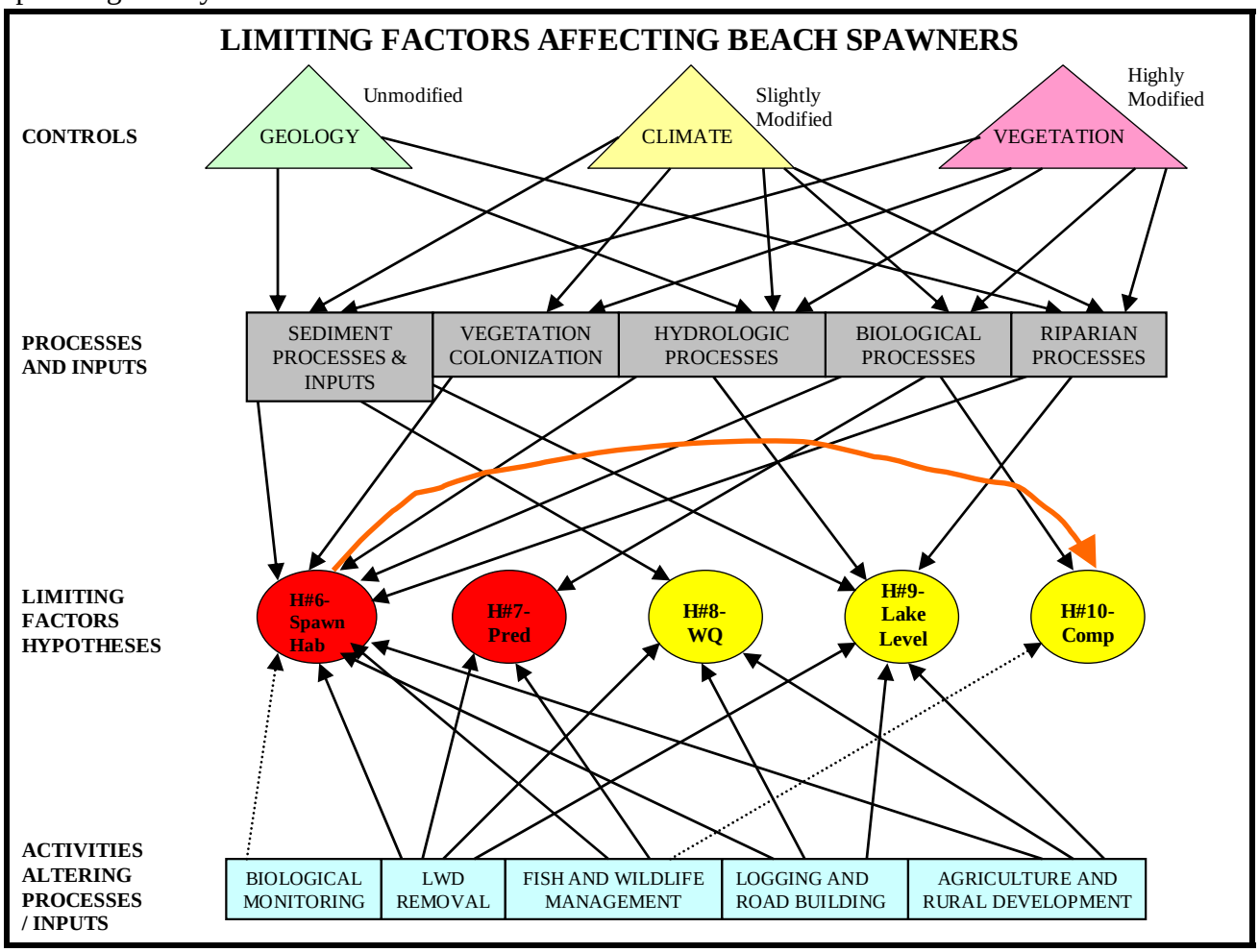

Figure 6.9. Schematic diagram depicting the linkage between watershed controls, watershed scale processes and inputs, limiting factors hypotheses, and activities that alter processes and inputs for beach spawning sockeye.

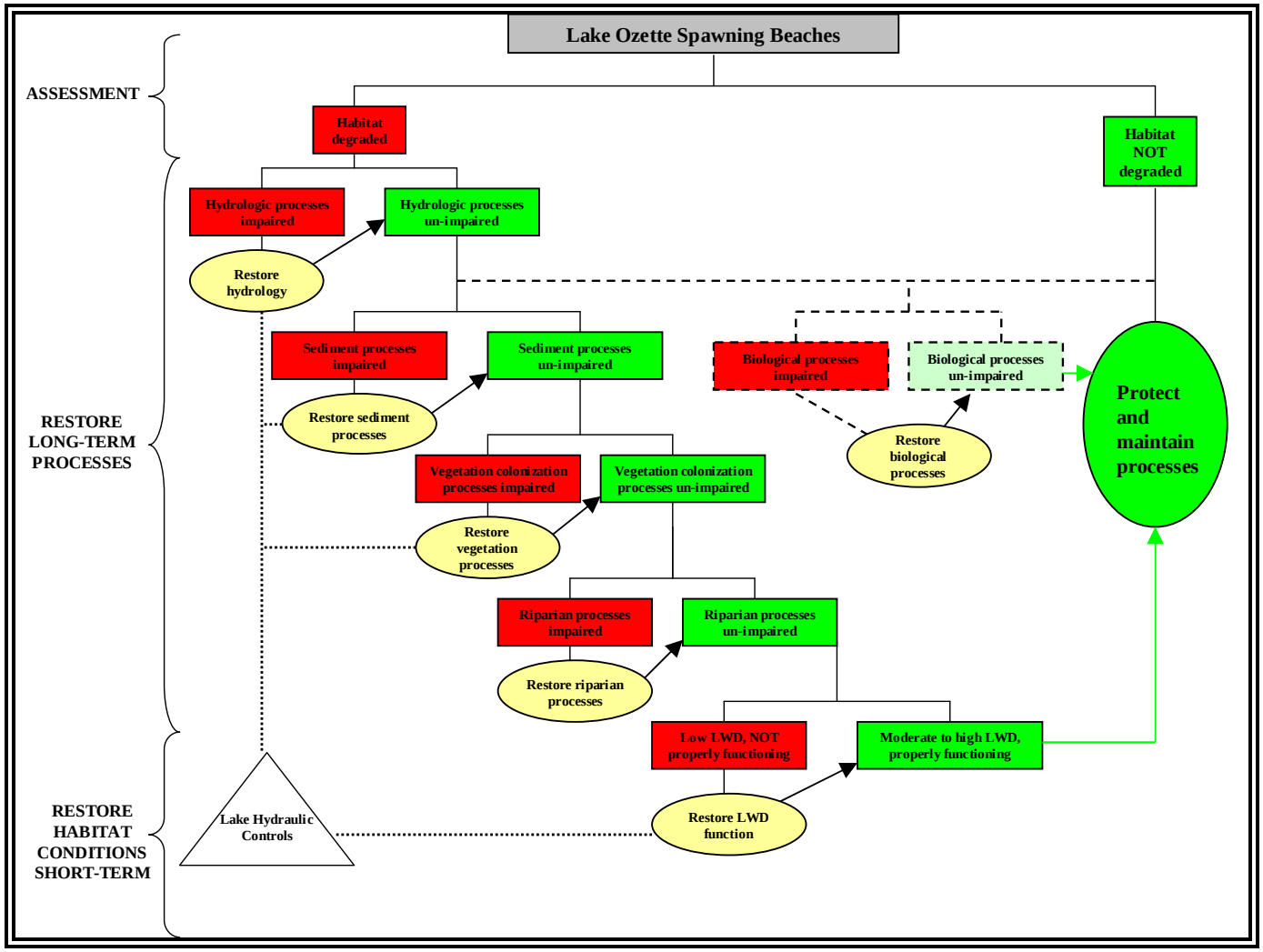

Figure 6.10. Flow chart depicting hierarchical strategy for prioritizing protection, restoration, and enhancement activities for factors affecting beach spawners (adapted from Roni et al. 2002).

6.3.1 Hydrologic Processes (H#6-BSH; H#9-LL)

Within the context of this subsection, hydrologic processes are those processes that store, deliver, and route water into Lake Ozette. Limiting factor Hypotheses 6 (Section 4.3.1.1) and 9 (Section 4.3.2.2) are the primary limiting factor hypotheses related to hydrologic processes affecting beach spawners. Hypothesis 6 is a key limiting factor hypothesis and is highly influenced by two primary processes: hydrology and sediment. Secondary processes, such as vegetation colonization, may be strongly influenced by the primary processes, as well as other secondary processes such as biological processes (e.g., habitat maintenance caused by the act of spawning, elk browsing). Figure 6.9 depicts the complexity and interconnectivity among controls, processes and inputs, hypotheses, and activities that affect processes and inputs.

Lake Ozette hydrology is largely controlled by: a) climate, b) lake and tributary hydrology, and c) LWD recruitment and storage (in logjams) in the upper one mile of the Ozette River. Activities affecting hydrologic processes include: historical LWD removal (affecting lake hydrology), ONP facilities operation and maintenance in Ozette River riparian zone (affecting LWD recruitment and lake hydrology), logging and road building throughout the watershed (affecting tributary hydrology and lake hydrology), agriculture and rural development in the Big River valley (affecting tributary and lake hydrology), and other floodplain alterations in major tributaries to the lake (affecting tributary and lake hydrology). Table 6.9 is a summary of the status (impaired/unimpaired) of hydrologic processes, linkage to limiting factors hypotheses, and activities affecting hydrologic processes.

Table 6.9 Summary of hydrologic process condition, linkage to limiting factors hypotheses, and activities affecting hydrologic processes.

Process/input condition status:	Impaired
Primary limiting factor hypotheses associated with process/input:	Hypotheses 6 (BSH) and 9 (LL)
Geographic location of limiting factor:	Lake Ozette
Life history stages affected:	Egg incubation and emergence and dispersal
Degree of impact of primary limiting factor hypothesis:	High (H#6-BSH) Key limiting factor Low (H#9-LL) Contributing Limiting Factor
Secondary limiting factors hypotheses associated with process/input:	NA
Activities and/or conditions affecting process/input:	LWD removal, ONP facilities, logging and road building, agriculture and rural development, and other floodplain alterations

Recovery goal: Restore hydrologic processes and natural hydrologic variability in the Ozette River to the extent that hydrologic influences on limiting factors (hypotheses 6 and 9) are no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 8: Quantitatively assess hydrologic impacts from land use and LWD removal activities and develop a distributed hydrologic model calibrated for each tributary in conjunction with Ozette River hydraulic model to prioritize actions needed to improve natural hydrologic functions.
Recovery strategy hierarchy: Tier 1.
Priority subbasin rating: Priority I.

Recovery strategy 9: Restore natural hydraulic controls (both LWD and sediment) in the Ozette River based on guidance from watershed hydrologic modeling.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I.

Recovery strategy 11: Based on the results of watershed hydrologic modeling implement hydrologic strategies to restore Lake Ozette inflow hydrology in priority II and III subbasins.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I, II, and III.

6.3.2 Sediment Processes (H#6-BSH; H#8-WQ)

Within the context of this subsection, sediment processes are those processes that store, deliver, and route sediment into Lake Ozette. Limiting factor Hypotheses 6 (Section 4.3.1.1) and 8 (Section 4.3.2.1) are the primary limiting factor hypotheses related to sediment processes affecting beach spawners. As described above, Hypothesis 6 is a key limiting factor hypothesis and is strongly influenced by two primary processes: hydrology and sediment. Beach spawning habitat conditions are highly variable around Lake Ozette. Spawning habitat quality and quantity impacts related to sediment processes vary by location due to differences in local sediment inputs. It has been hypothesized that increased sediment load in tributaries from land use activities (primarily logging and road building) and consequent delivery to lake beaches has decreased the quality and quantity of beach spawning habitat that is available for successful egg incubation, contributing to the elimination of at least one of the historical spawning subpopulations (Haggerty et al. 2007). Activities affecting sediment processes include: logging and road building throughout the watershed (affecting sediment supply), agriculture and rural development in the Big River valley (affecting sediment supply and Lake Ozette water quality), and other floodplain alterations (e.g., wood removal in Big River) in tributaries to the lake. Table 6.10 is a summary of the status (impaired/unimpaired) of sediment processes, linkage to limiting factors hypotheses, and activities affecting sediment processes.

Table 6.10 Summary of sediment process condition, linkage to limiting factors hypotheses, and activities affecting sediment processes.

Process/input condition status:	Impaired
Primary limiting factor hypotheses associated with process/input:	Hypotheses 6 (BSH) and 8 (WQ)
Geographic location of limiting factor:	Lake Ozette
Life history stages affected:	Adult staging and spawning (H#8-WQ only) egg incubation and emergence and dispersal
Degree of impact of primary limiting factor hypothesis:	High (H#6-BSH) Key limiting factor Low (H#8-WQ) Contributing Limiting Factor
Secondary limiting factors hypotheses associated with process/input:	Hypothesis 10 (Comp)
Activities and/or conditions affecting process/input:	LWD removal and altered lake levels, logging and road building, agriculture and rural development, and other floodplain alterations

Recovery goal: Restore natural sediment production, storage, and transport processes in Lake Ozette tributaries to the extent that sediment (per limiting factors hypotheses 6, 8, and 10) is no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 17: Within the Umbrella Creek subbasin, quantitatively assess sediment level impacts from logging (gully creation, landslides), road building, LWD removal, channel instability, and floodplain connectivity. Develop program to eliminate and/or reduce landuse-related sediment inputs to levels that create properly functioning conditions at Umbrella Beach.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I

Recovery strategy 18: Within the Big River subbasin, quantitatively assess sediment impacts from logging (gully creation, landslides), road building, LWD removal, channel instability, floodplain connectivity, and other land use activities. Develop program to eliminate and/or reduce landuse-related sediment inputs to levels that do not create water quality problems within the lake.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

Recovery strategy 19: Within priority II and III subbasins, quantitatively assess sediment impacts from logging (gully creation, debris flows, landslides), road building, LWD removal, channel instability, and floodplain connectivity. Develop program to eliminate and/or reduce landuse-related sediment inputs that have the potential to deliver sediment to lakeshore spawning habitats or areas identified as potential habitat.

Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

6.3.3 Riparian Processes and Vegetation Colonization (H#6-BSH)

Within the context of this subsection, riparian processes are limited in geographic scope to the perimeter of Lake Ozette. Limiting factor Hypothesis 6 is the primary hypothesis related to riparian processes affecting beach spawners. Aerial photo evidence indicates that most stable LWD along the shoreline is locally recruited from erosion or windfall. Large woody debris in and adjacent to spawning habitat provides cover from predators. Additionally, shoreline wood functions to cleanse gravel locally and scour colonizing vegetation through turbulence. Riparian conditions are excellent around most of the lake; however, an unknown quantity of LWD was historically removed from the perimeter of the lake. Vegetation colonization of spawning habitat has also been identified as a factor affecting the quantity and quality of beach spawning habitat in Lake Ozette. Vegetation colonization processes are thought to be affected primarily by lake levels, which are controlled by the lake's hydrologic processes, which are strongly influenced by LWD inputs and conditions in the upper Ozette River. Sediment inputs and changes in substrate particle size can also affect vegetation's ability to colonize the lake's shoreline. The primary activities that contribute to degraded riparian conditions, where they exist, are the development and maintenance of ONP facilities, past construction and maintenance of infrastructure on private property within the boundaries of ONP, and historical homesteading. Table 6.11 is a summary of the status (impaired/unimpaired) of riparian input processes, linkage to limiting factors hypotheses, and activities affecting riparian processes.

Table 6.11 Summary of riparian processes condition, linkage to limiting factors hypotheses, and activities affecting riparian processes.

Process/input condition status:	Impaired
Primary limiting factor hypotheses associated with process/input:	Hypothesis 6 (BSH)
Geographic location of limiting factor:	Lake Ozette
Life history stages affected:	Egg incubation and emergence and dispersal; adult staging and spawning (H#9-LL only)
Degree of impact of primary limiting factor hypothesis:	High Key limiting factor
Secondary limiting factors hypotheses associated with process/input:	Hypothesis 9 (LL)
Activities and/or conditions affecting process/input:	LWD removal, logging and road building, agriculture and rural development, and other floodplain alterations

Recovery goal: Maintain and protect the lake's riparian forest. Restore riparian and shoreline vegetation colonization processes around Lake Ozette where conditions are degraded to the extent that riparian and shoreline vegetation influences on limiting factors are no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 20: Maintain and protect the lake's riparian forest. Determine where degraded riparian forests exist that may affect spawning habitat quality, and re-establish native riparian vegetation. Implement recovery strategies to restore hydrologic processes (RS#8-11) and sediment processes (RS#17-19).
Recovery strategy hierarchy: Tier 1 and 3.
Priority subbasin rating: Priority I

Recovery strategy 21: Survey and eradicate non-native invasive plant species colonizing the lake's beaches and riparian areas. This may require non-native species eradication in all tributaries to be successful over the long-term.
Recovery strategy hierarchy: Tier 4.
Priority subbasin rating: Priority I.

6.3.4 Biological Processes (H#7-Pred)

Within the context of this subsection, biological processes are those biological processes that occur in Lake Ozette that affect only beach spawners. Limiting factor Hypothesis 7 (Section 4.3.1.2) is the primary limiting factor hypothesis related to biological processes affecting the beach spawning population segment. However, biological processes also have the potential to alter habitat conditions, e.g. sockeye salmon can maintain habitat quality along the beaches through the process of spawning, where young vegetation and fine sediment can be displaced from the spawning gravels. The reduced quantity of high quality spawning habitat at Olsen's Beach results in significant levels of competition during periods of moderate abundance. Biological processes in fresh water are complex, since many watershed-scale processes, habitat conditions, and management activities may affect biological processes and ultimately the predator-prey balance within the ecosystem. Activities and/or conditions that currently affect predation include: past LWD removal, current habitat conditions on spawning beaches, biological monitoring, and fish and wildlife management. Table 6.12 is a summary of the status of biological processes, linkage to limiting factors hypotheses, and activities affecting predation

Table 6.12. Summary of biologic process condition, linkage to limiting factors hypotheses, and activities affecting biological processes.

Process/input condition status:	Impaired
Primary limiting factor hypothesis associated with process/input:	Hypothesis 7 (Pred)
Geographic location of limiting factor:	Lake Ozette
Life history stages affected:	Egg incubation and emergence and dispersal; adult staging and spawning
Degree of impact of primary limiting factor hypothesis:	High Key limiting factor
Secondary limiting factors hypotheses associated with process/input:	Hypotheses 6 (BSH) and 10 (Comp)
Activities and/or conditions affecting predation:	Past LWD removal, current habitat conditions at spawning beaches, biological monitoring, fish and wildlife management

Recovery goal: Restore and protect biological processes so that freshwater predation, habitat maintenance, and competition are no longer limiting Lake Ozette sockeye viability.

Recovery strategy 22: Implement strategies and actions to increase egg-to-fry survival of beach and tributary spawners so that the habitat can produce abundant sockeye salmon, reducing the overall percent impact of predation on the population.
Recovery strategy hierarchy: Tier 3-4.
Priority subbasin rating: Priority I.

Recovery strategy 23: Increase the spatial distribution of Lake Ozette beach spawning sockeye.
Recovery strategy hierarchy: Tier 2.
Priority subbasin rating: Priority I.

Recovery strategy 24: Restore natural predator-prey balance by reducing pre-spawn predation mortalities.
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

6.3.5 Habitat Conditions (H#6-BSH)

Within the context of this subsection, habitat conditions are limited in geographic scope to beach spawning habitat along the shoreline of the lake. Limiting factor Hypothesis 6 (Section 4.3.1.1) is the primary limiting factor hypothesis related to habitat conditions affecting beach spawners. Lake Ozette beach spawning habitat conditions are controlled by: a) lake and tributary hydrology, b) tributary sediment processes, and c) vegetation

colonization processes. Riparian and biological processes also influence beach spawning habitat quantity and quality. Activities affecting habitat conditions include: historical LWD removal (Ozette River), ONP facilities operation and maintenance in Ozette River riparian zone (affecting LWD recruitment), logging and road building throughout the watershed, past and current agriculture and rural development, and fish and wildlife management. Table 6.13 is a summary of the status (impaired/unimpaired) of habitat conditions, linkage to limiting factors hypotheses, and activities affecting habitat conditions.

Table 6.13 Summary of habitat conditions, linkage to limiting factors hypotheses, and activities affecting habitat conditions.

Habitat condition status:	Impaired
Primary limiting factor hypotheses associated with process/input:	Hypothesis 6 (BSH)
Geographic location of limiting factor:	Lake Ozette shoreline
Life history stages affected:	Egg incubation, emergence and dispersal
Degree of impact of primary limiting factor hypothesis:	High Key limiting factor
Secondary limiting factors hypotheses associated with process/input:	NA
Processes affecting habitat conditions:	• Hydrologic processes • Sediment processes • Riparian processes • Vegetation colonization • Biological processes

Recovery goals: Increase the quantity and quality of beach spawning habitat in Lake Ozette so that habitat quantity and quality are no longer limiting factors affecting sockeye VSP parameters.

Recovery strategy 25: Develop a comprehensive understanding of the conditions, factors, and processes controlling egg-to-fry survival on sockeye spawning beaches. Investigate several different methods of beach spawning habitat rehabilitation, including: vegetation removal, gravel cleaning, LWD introduction, and others. Include sockeye egg survival studies with habitat manipulations.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I.

6.4 GOALS AND STRATEGIES TO RESTORE PROCESSES AND CONDITIONS AFFECTING TRIBUTARY SPAWNERS

Section 4.4 identifies and describes limiting factors affecting only tributary spawning sockeye. All tributary spawning sockeye experience similar habitat conditions and limiting factors during four life history stages: adult migration (Ozette sockeye spawning tributaries), adult holding (tributaries), egg incubation (tributaries), and emergence and dispersal (tributaries). Each limiting factor was assessed based upon the sockeye life stage affected, the process or input influencing the limiting factors, and activities that affect each process and input. Figure 6.11 illustrates the interconnectedness between different processes and limiting factors relative to the tributary spawning population segment. It is important to note how complex and interconnected the processes and limiting factors are, because the following subsections present this information in a highly simplified manner. Figure 6.10 depicts a hierarchical strategy for prioritizing protection, restoration, and enhancement activities for tributary spawning sockeye.

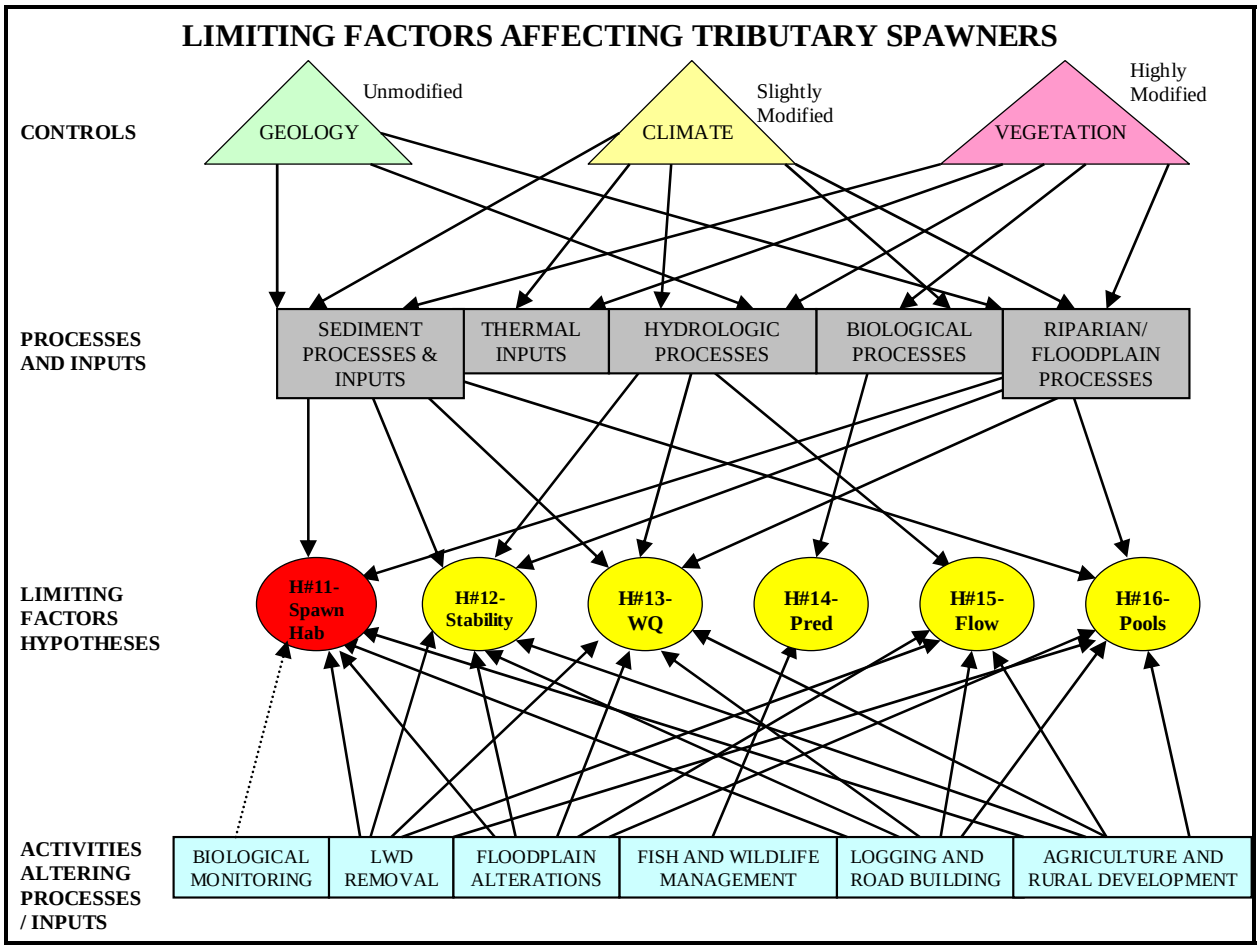

Figure 6.11. Schematic diagram depicting the linkage between watershed controls, watershed scale processes and inputs, limiting factors hypotheses, and activities that alter processes and inputs for tributary spawning sockeye.

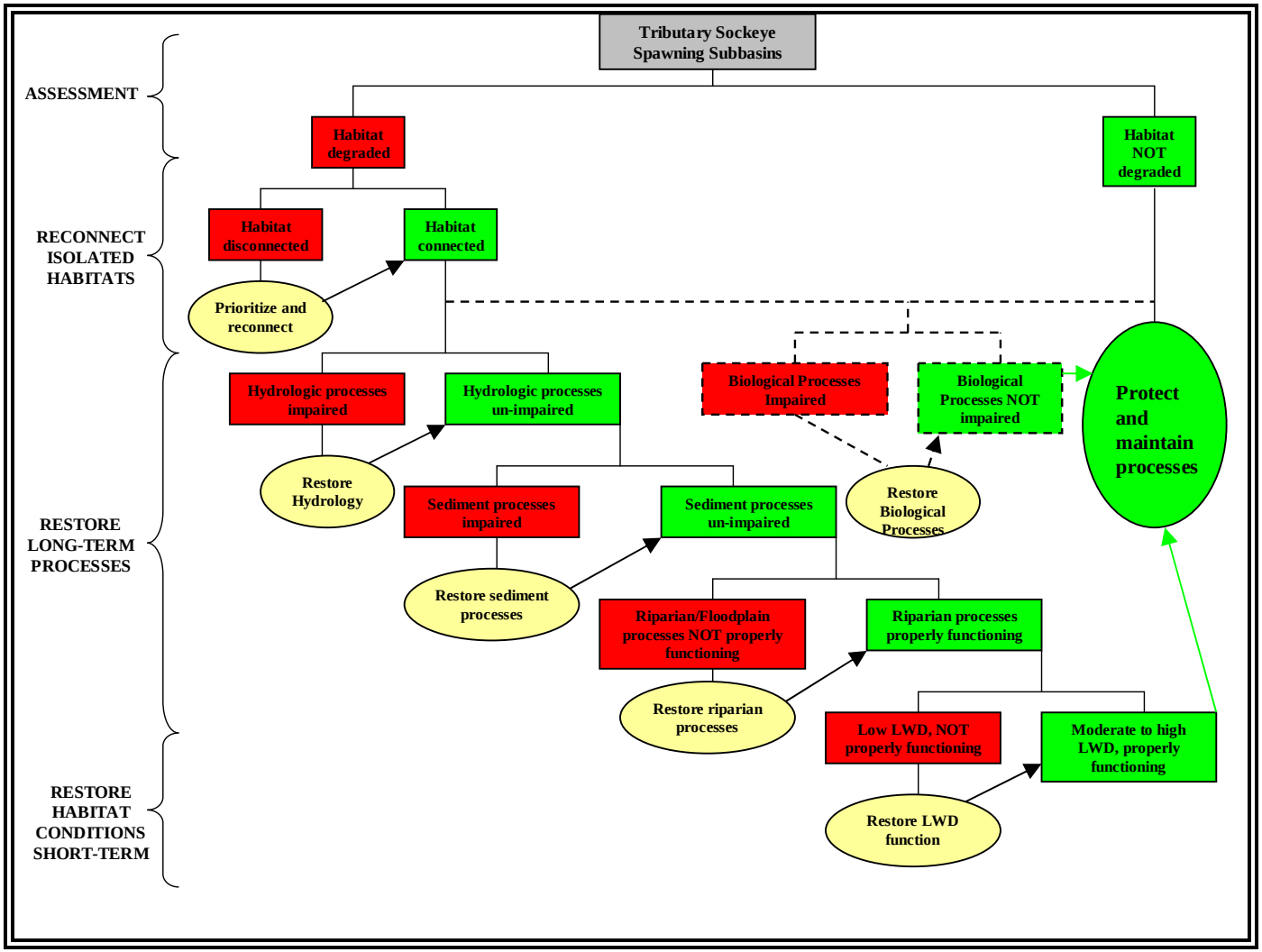

Figure 6.12. Flow chart depicting hierarchical strategy for prioritizing protection, restoration, and enhancement activities for factors affecting tributary spawners (adapted from Roni et al. 2002).

6.4.1 Habitat Connectivity

Within the context of this subsection, habitat connectivity relates to Lake Ozette tributary sockeye migration barriers created by humans. Currently there are no migration barriers to Lake Ozette sockeye within tributaries that are currently utilized by sockeye. However, as the spatial distribution of spawning sockeye changes during the population rebuilding period, areas currently unoccupied may become occupied. Barriers, if they exist or if new ones are created, could limit the spatial distribution of sockeye. Table 6.14 is a summary of the status of habitat connectivity, linkage to limiting factors hypotheses, and activities affecting habitat connectivity.

Table 6.14 Summary of habitat connectivity condition, linkage to limiting factors hypotheses, and activities affecting habitat connectivity.

Process/input condition status:	Unimpaired
Primary limiting factor hypothesis associated with process/input:	NA
Geographic location of limiting factor:	Ozette sockeye tributaries
Life history stages affected:	None
Degree of impact of primary limiting factor hypothesis:	NA
Secondary limiting factors hypotheses associated with process/input:	NA
Activities and/or conditions affecting process/input:	None identified

Recovery goal: Maintain and protect habitat connectivity.

Recovery strategy 26: Implement programmatic actions to ensure that habitat connectivity is maintained. As sockeye spawning spatial distribution increases, ensure that fish blockages are corrected within stream reaches suitable for sockeye spawning.
Recovery strategy hierarchy: Tier 1.
Priority subbasin rating: Priority I and II.

6.4.2 Hydrologic Processes (H#15-Q)

Within the context of this subsection, hydrologic processes are those processes that store, deliver, and route water in Lake Ozette sockeye spawning tributaries. Limiting factor Hypothesis 15 (Section 4.4.2.4) is the primary limiting factor hypothesis related to hydrologic processes affecting tributary spawners. Hypothesis 15 is a contributing limiting factor hypothesis and may influence other processes and conditions (e.g., channel stability and water quality). Tributary hydrology is largely controlled by climate; therefore, future threats such as climate change (e.g., decreased summer precipitation and increased winter precipitation) have the potential to further degrade hydrologic conditions

for tributary spawning sockeye. Figure 6.9 depicts the complexity and interconnectivity among controls, processes and inputs, hypotheses, and activities that affect processes and inputs. Activities affecting hydrologic processes in tributaries include: logging and road building throughout the watershed, agriculture and rural development, and other floodplain alterations in major tributaries. A summary of the status of hydrologic processes, linkage to limiting factors hypotheses, and activities affecting hydrologic processes is shown in Table 6.15. Tributary hydrologic processes also transcend population segment boundaries and can affect habitat-forming processes and habitat conditions, as well as biological processes influencing all population segments.

Table 6.15. Summary of hydrologic process condition, linkage to limiting factors hypotheses, and activities affecting hydrologic processes.

Process/input condition status:	Impaired
Primary limiting factor hypotheses associated with process/input:	Hypothesis 15 (Q)
Geographic location of limiting factor:	Lake Ozette
Life history stages affected:	Adult migration and pre-spawning holding, egg incubation, and emergence and dispersal
Degree of impact of primary limiting factor hypothesis:	Unknown Contributing limiting factor
Secondary limiting factors hypotheses associated with process/input[1]:	H#12-Stab; H#13-WQ
Activities and/or conditions affecting process/input:	Logging and road building, agriculture and rural development, and other floodplain alterations

[1]Tributary hydrologic processes also influence the following hypotheses: H#1-Pred, H#2-WQ, H#3-Q, H#4-Hab, H#6-BSH, and H#9-LL

Recovery goal: Restore hydrologic processes and natural hydrologic variability in Ozette tributaries to the extent that hydrologic influences on all limiting factors influenced by hydrologic processes are no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 27: Quantitatively assess hydrologic impacts from land use and LWD removal activities and develop a distributed hydrologic model calibrated for each sockeye tributary. Based on modeling results, prioritize actions needed to improve natural hydrologic processes in sockeye spawning streams.
Recovery strategy hierarchy: Tier 1.
Priority subbasin rating: Priority I.

6.4.3 Sediment Processes (H#11-TSH;H#13-WQ)

Within the context of this subsection, sediment processes are those processes that store, deliver, and route sediment in Lake Ozette sockeye spawning tributaries. Limiting factor Hypotheses 11 (Section 4.4.1.1) and 13 (Section 4.4.2.2) are the primary limiting factor hypotheses related to sediment processes affecting tributary spawners. Sediment processes also influence limiting factor Hypotheses 12 and 16. Gravel storage behind large woody debris has been systematically reduced from historical levels; this coupled with increased fine sediment delivery to mainstem spawning reaches has altered the quantity and quality of spawning habitat. Increased sediment inputs into sockeye spawning streams can also contribute to degraded water quality conditions. The high road densities in spawning tributaries (averaging >6.0 mi/mi2), extensive clear-cutting (>95 percent of Umbrella Creek and Big River watershed clear-cut at least once), increased channel instability, mass wasting events, and other land use activities (e.g., agriculture) all contribute to elevated turbidity and SSC levels in tributaries. Activities affecting sediment processes include: logging and road building throughout the watershed (affecting sediment supply), agriculture and rural development in the Big River valley, and other floodplain alterations (e.g., wood removal in Big River) in tributaries to the lake. Table 6.16 is a summary of the status (impaired/unimpaired) of sediment processes, linkage to limiting factors hypotheses, and activities affecting sediment processes.

Table 6.16 Summary of sediment process condition, linkage to limiting factors hypotheses, and activities affecting sediment processes.

Process/input condition status:	Impaired
Primary limiting factor hypothesis associated with process/input:	Hypotheses 11 (TSH) and 13 (WQ)
Geographic location of limiting factor:	Lake Ozette
Life history stages affected:	Adult staging and spawning (H#8-WQ only) egg incubation and emergence and dispersal
Degree of impact of primary limiting factor hypothesis:	High (H#11-TSH) Key limiting factor Low (H#13-WQ) Contributing limiting factor
Secondary limiting factors hypotheses associated with process/input:	H#12 (Stab) and H#16 (HP)
Activities and/or conditions affecting process/input:	LWD removal, logging and road building, agriculture and rural development, and other floodplain alterations

Recovery goal: Restore natural sediment production, storage, and transport processes in Lake Ozette tributaries to the extent that sediment (per limiting factors Hypothesis 11) is no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 28: Within the sockeye spawning subbasins, quantitatively assess sediment impacts from logging (gully creation, landslides), road building, LWD removal,

and other land use activities. Develop program to eliminate and/or reduce land use-related sediment inputs to levels that create properly functioning conditions within these subbasins (this should be done in conjunction with RS#17-19).
Recovery strategy hierarchy: Tier 3.
Priority subbasin rating: Priority I.

6.4.4 Riparian and Floodplain Processes (H#11-TSH; H#12-Stab)

Within the context of this subsection, riparian and floodplain processes are limited in geographic scope to the following three watersheds: Umbrella Creek, Big River, and Crooked Creek. Riparian and floodplain processes influence hydrologic and sediment processes, which in turn affect limiting factor Hypotheses 11, 12, 13, and 16. For example, riparian and floodplain processes can affect spawning habitat quantity by recruiting LWD, which then stores spawning gravel. Large wood also maintains floodplain connectivity, which then results in more fine sediment storage on the floodplain versus the active channel. Riparian and floodplain processes also influence channel stability.

Loss of riparian function (including in-channel LWD) and floodplain connectivity results in channel destabilization and/or morphologic changes in channel form and can result in lowered egg-to-fry survival during the egg incubation period. The primary activities that contribute to degraded riparian and floodplain conditions where they exist are the historical removal of LWD, logging and road building, agriculture and rural development, and other floodplain alterations (e.g., bank armoring). Table 6.17 is a summary of the status of riparian and floodplain processes, linkage to limiting factors hypotheses, and activities affecting riparian-floodplain processes.

Table 6.17 Summary of riparian and floodplain processes condition, linkage to limiting factors hypotheses, and activities affecting riparian and floodplain processes.

Process/input condition status:	Impaired
Primary limiting factor hypothesis associated with process/input:	H#11-TSH; H#12-Stab
Geographic location of limiting factor:	Lake Ozette
Life history stages affected:	Egg incubation and emergence and dispersal
Degree of impact of primary limiting factor hypothesis:	High (H#11-TSH) Key limiting factor Unknown (H#12-Stab) Contributing limiting factor
Secondary limiting factors hypotheses associated with process/input:	H#13-WQ; H16-HP
Activities and/or conditions affecting process/input:	LWD removal, logging and road building, agriculture and rural development, and other floodplain alterations

Recovery goal: Restore riparian and floodplain processes and conditions in sockeye spawning tributaries to the extent that riparian and floodplain processes are no longer limiting Lake Ozette sockeye VSP parameters.

Recovery strategy 29: Protect riparian forests and reestablish healthy riparian forests where degraded conditions exist within sockeye spawning subbasins.
Recovery strategy hierarchy: Tier 1/3.
Priority subbasin rating: Priority I/II.

Recovery strategy 30: Survey and eradicate non-native invasive plant species colonizing riparian areas.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I/II.

Recovery strategy 31: Identify riparian/floodplain infrastructure; where feasible, develop alternatives to mitigate or remove infrastructure-impairing riparian/floodplain processes.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I.

Recovery strategy 32: Identify disconnected floodplain surfaces and add LWD to reconnect floodplains to channels to improve connectivity, sediment storage, water retention, and peak flow attenuation.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I.

6.4.5 Biological Processes

Within the context of this subsection, biological processes are limited to those that occur in tributaries and affect only tributary spawners. Biological processes within tributary spawning subbasins influence limiting factor Hypothesis 14. Currently biological processes are only slightly impaired. Fish and wildlife management is the activity identified that affects biological processes within Ozette sockeye spawning subbasins. Table 6.18 is a summary of the status of biological processes, linkage to limiting factors hypotheses, and activities affecting biological processes.

Table 6.18 Summary of hydrologic process condition, linkage to limiting factors hypotheses, and activities affecting hydrologic processes.

Process/input condition status:	Slightly impaired
Primary limiting factor hypothesis associated with process/input:	NA
Geographic location of limiting factor:	Ozette sockeye tributaries
Life history stages affected:	Adult migration and holding, egg incubation, emergence and dispersal
Degree of impact of primary limiting factor hypothesis:	NA
Secondary limiting factors hypotheses associated with process/input:	Hypothesis 14 (Pred)
Activities and/or conditions affecting process/input:	Fish and wildlife management

Recovery goal: Maintain and protect biological processes in sockeye spawning subbasins. Increase spatial distribution of sockeye salmon in Umbrella Creek and Big River.

Recovery strategy 32: Increase the spatial distribution of tributary spawning sockeye by implementing the LOS HGMP.
Recovery strategy hierarchy: Tier 1.
Priority subbasin rating: Priority I and II.

6.4.6 Habitat Conditions (H#11-TSH)

Within the context of this subsection, habitat conditions are limited in geographic scope to tributary sockeye spawning. Limiting factor Hypothesis 11 (Section 4.4.1.1) is the primary limiting factor hypothesis related to habitat conditions affecting tributary spawners. Lake Ozette tributary spawning habitat conditions are controlled by sediment, hydrologic, and riparian-floodplain processes. Activities affecting habitat conditions include: historical LWD removal (altering lake base level), logging and road building throughout the watershed, past and current agriculture and rural development. Table 6.19 is a summary of the status of habitat conditions, linkage to limiting factors hypotheses, and activities affecting habitat conditions.

Table 6.19 Summary of habitat conditions, linkage to limiting factors hypotheses, and activities affecting habitat conditions.

Habitat condition status:	Impaired
Primary limiting factor hypothesis associated with process/input:	Hypothesis 11 (TSH)
Geographic location of limiting factor:	Ozette sockeye tributaries
Life history stages affected:	Egg incubation, emergence and dispersal
Degree of impact of primary limiting factor hypothesis:	High Key limiting factor
Secondary limiting factors hypotheses associated with process/input:	NA
Processes affecting habitat conditions:	• Sediment processes • Riparian-floodplain processes • Biological processes

Recovery goals: Increase the quantity and quality of spawning habitat in sockeye spawning tributaries so that habitat quantity and quality do not limit sockeye VSP parameters.

Recovery strategy 33: Add LWD structures throughout sockeye spawning streams where gravel deficient conditions exist, to trap and store spawning gravels. This must be done in conjunction with or after sediment and hydrologic processes are addressed.
Recovery strategy hierarchy: Tier 3/4.
Priority subbasin rating: Priority I.

6.5 SUMMARY OF LAKE OZETTE SOCKEYE RECOVERY STRATEGIES

The recovery strategies identified in this plan address the limiting factors hypotheses for Lake Ozette sockeye. Table 6.20 summarizes the recovery strategies presented in the sections above. The goal of the recovery plan is to address limiting factors and implement recovery strategies that will improve the viable salmonid population parameters (see Table 3.1) such that, over time, each parameter will achieve or exceed the PSTRT's proposed viability criteria. In order to track and measure changes in these viability parameters as recovery actions are implemented, a detailed adaptive management, research, monitoring and evaluation plan will be developed in 2008 (see Chapter 8). Based on monitoring results, the adaptive management plan will adjust recovery actions so that viability parameters improve over time. Proposed monitoring will further our understanding of how habitat conditions affect sockeye viability parameters, and will accordingly help identify what recovery actions are needed to improve viability. Thus, the link between recovery strategies and expected viability responses will be better understood as both proposed actions and proposed monitoring proceed.

Table 6.20. Summary of Lake Ozette sockeye salmon recovery strategies.

Recovery Strategy ID	Recovery Flow Chart (Population Segment Addressed)	Process, Input, or Condition	Description	Primary Hypotheses Addressed	Secondary Hypotheses Addressed
RS#1	All Population Segments	Coastal Processes	Protect coastal processes and estuary habitat from degradation by implementing ONP and Marine Sanctuary regulations and management plans.	NA	NA
RS#2	All Population Segments	Biological	Implement strategies and actions to increase egg-to-fry survival of beach and tributary spawners so that the habitat can produce abundant sockeye salmon capable of overwhelming and swamping predators, and thus maintain a natural predator-prey balance.	H#1 (Pred)	NA
RS#3	All Population Segments	Biological	Restore natural predator-prey balance by eliminating non-native fish species.	H#1 (Pred)	NA
RS#4	All Population Segments	Biological	Restore natural predator-prey balance by eliminating and/or strictly limiting fishing related mortalities on Lake Ozette sockeye.	H#1 (Pred)	NA
RS#5	All Population Segments	Biological	Improve predator avoidance opportunities in the Ozette River (e.g., improved weir and smolt trapping techniques).	H#1 (Pred)	NA
RS#6	All Population Segments	Biological	Implement actions that restore the hydraulic and hydrologic (e.g., LWD and sediment deposition) conditions of the Ozette River to provide favorable flow conditions for sockeye migration and predator avoidance.	H#1 (Pred)	NA
RS#7	All Population Segments	Biological	Work at local, regional, and international scales to maintain favorable ocean conditions that support sockeye salmon.	H#1 (Pred)	H#5 (MS)

Recovery Strategy ID	Recovery Flow Chart (Population Segment Addressed)	Process, Input, or Condition	Description	Primary Hypotheses Addressed	Secondary Hypotheses Addressed
RS#8	All Population Segments	Hydrology	Quantitatively assess hydrologic impacts from land use and LWD removal activities and develop a distributed hydrologic model calibrated for each tributary in conjunction with Ozette River hydraulic model to prioritize actions needed to improve natural hydrologic functions where needed.	H#3 (Q)	H#1 (Pred) H#2 (WQ) H#4 (Hab)
RS#9	All Population Segments	Hydrology	Restore natural hydraulic controls (both LWD and sediment) in the Ozette River based on guidance from watershed hydrologic modeling.	H#3 (Q)	H#1 (Pred) H#2 (WQ) H#4 (Hab)
RS#10	All Population Segments	Hydrology	Implement hydrologic strategies for sockeye spawning subbasins based on outcome of hydrologic modeling (see Section 6.4.2 recovery strategies).	H#3 (Q)	H#1 (Pred) H#2 (WQ) H#4 (Hab)
RS#11	All Population Segments	Hydrology	Based on the results of watershed hydrologic modeling, implement hydrologic strategies to restore Lake Ozette inflow hydrology in priority II and III subbasins.	H#3 (Q)	H#1 (Pred) H#2 (WQ) H#4 (Hab)
RS#12	All Population Segments	Sediment	Within the Coal Creek subbasin, quantitatively assess sediment production impacts from logging (gully creation, landslides), road building, and LWD removal. Develop program to eliminate and/or reduce land use-related sediment inputs. Implement sediment reduction program.	H#2 (WQ) H#3 (Q)	H#1 (Pred) H#4 (Hab)
RS#13	All Population Segments	Sediment	Restore natural hydraulic controls (both LWD and Sediment) in the Ozette River based on guidance from watershed hydrologic modeling.	H#3 (Q)	H#1 (Pred) H#2 (WQ) H#4 (Hab)

Recovery Strategy ID	Recovery Flow Chart (Population Segment Addressed)	Process, Input, or Condition	Description	Primary Hypotheses Addressed	Secondary Hypotheses Addressed
RS#14	All Population Segments	Thermal Inputs	Stop or significantly slow climate change by developing and participating in local, regional, national, and global atmospheric anti-pollution program to reduce emissions of greenhouse gases. If this cannot be accomplished then a comprehensive mitigation plan must be developed.	H#2 (WQ)	H#5 (MS)
RS#15	All Population Segments	Thermal Inputs	Protect Ozette River riparian corridor and reestablish riparian forest where degraded conditions exist.	H#2 (WQ)	NA
RS#15	All Population Segments	Riparian Processes	Protect Ozette River riparian corridor and reestablish riparian forest where degraded conditions exist.	NA	H#1 (Pred) H#3 (Q) H#4 (Hab)
RS#16	All Population Segments	Habitat Condition	Use LWD placement techniques to restore LWD habitat conditions in the Ozette River. This should be conducted in conjunction with strategies to restore lake and river hydrology-hydraulics.	H#4 (Hab)	H#1 (Pred) H#3 (Q)
RS#8	Beach Spawners	Hydrology	Quantitatively assess hydrologic impacts from land use and LWD removal activities and develop a distributed hydrologic model calibrated for each tributary in conjunction with Ozette River hydraulic model to prioritize actions needed to improve natural hydrologic functions where needed.	H#6 (BSH) H#9 (LL)	NA
RS#9	Beach Spawners	Hydrology	Restore natural hydraulic controls (both LWD and sediment) in the Ozette River based on guidance from watershed hydrologic modeling.	H#6 (BSH) H#9 (LL)	NA

Recovery Strategy ID	Recovery Flow Chart (Population Segment Addressed)	Process, Input, or Condition	Description	Primary Hypotheses Addressed	Secondary Hypotheses Addressed
RS#11	Beach Spawners	Hydrology	Based on the results of watershed hydrologic modeling, implement hydrologic strategies to restore Lake Ozette inflow hydrology in priority II and III subbasins.	H#6 (BSH) H#9 (LL)	NA
RS#17	Beach Spawners	Sediment	Within the Umbrella Creek subbasin, quantitatively assess sediment production impacts from logging (gully creation, landslides), road building, and LWD removal. Develop program to eliminate and/or reduce land use-related sediment inputs to levels that create properly functioning conditions at Umbrella Beach.	H#6 (BSH) H#8 (WQ)	H#10 (Comp)
RS#18	Beach Spawners	Sediment	Within the Big River subbasin quantitatively assess sediment production impacts from logging (gully creation, landslides), road building, LWD removal, and other land use activities. Develop program to eliminate and/or reduce land use-related sediment inputs to levels that do not create water quality problems within the lake.	H#8 (WQ)	NA
RS#19	Beach Spawners	Sediment	Within Priority II and III subbasins, quantitatively assess sediment production impacts from logging (gully creation, debris flows, landslides) and road building. Develop program to eliminate and/or reduce land use-related sediment inputs that have the potential to deliver sediment to lake shore spawning habitats or areas of identified as potential habitat.	H#6 (BSH) H#8 (WQ)	H#10 (Comp)

Recovery Strategy ID	Recovery Flow Chart (Population Segment Addressed)	Process, Input, or Condition	Description	Primary Hypotheses Addressed	Secondary Hypotheses Addressed
RS#20	Beach Spawners	Riparian Processes Vegetation Colonization	Maintain and protect the lake's riparian forest. Determine where degraded riparian forests exist that may affect spawning habitat quality and re-establish native riparian vegetation. Implement recovery strategies to restore hydrologic processes (RS#8-11) and sediment processes (RS#17-19).	H#6 (BSH)	H#9 (LL)
RS#21	Beach Spawners	Riparian Processes Vegetation Colonization	Survey and eradicate non-native invasive plant species colonizing the lake's beaches and riparian areas. This may require non-native species eradication in all tributaries to be successful over the long-term	H#6 (BSH)	H#9 (LL)
RS#22	Beach Spawners	Biological	Implement strategies and actions to increase egg-to-fry survival of beach and tributary spawners so that the habitat can produce abundant sockeye salmon capable of overwhelming and swamping predators, and thus maintain a natural predator-prey balance.	H#7 (Pred)	H#6 (BSH) H#10 (Comp)
RS#23	Beach Spawners	Biological	Increase the spatial distribution of Lake Ozette beach spawning sockeye.	H#7 (Pred)	H#6 (BSH) H#10 (Comp)
RS#24	Beach Spawners	Biological	Restore natural predator-prey balance by reducing pre-spawn predation mortalities.	H#7 (Pred)	H#6 (BSH) H#10 (Comp)
RS#25	Beach Spawners	Habitat Condition	Develop a comprehensive understanding of the conditions, factors, and processes controlling egg-to-fry survival on sockeye spawning beaches. Investigate several different methods of beach spawning habitat rehabilitation including: vegetation removal, gravel cleaning, LWD introduction, etc…Include sockeye egg survival studies with habitat manipulations.	H#6 (BSH)	NA

Recovery Strategy ID	Recovery Flow Chart (Population Segment Addressed)	Process, Input, or Condition	Description	Primary Hypotheses Addressed	Secondary Hypotheses Addressed
RS#26	Tributary Spawners	Habitat Connectivity	Implement programmatic actions to ensure that habitat connectivity is maintained. As sockeye spawning spatial distribution increases, ensure that fish blockages are corrected within stream reaches suitable for sockeye spawning.	NA	NA
RS#27	Tributary Spawners	Hydrology	Quantitatively assess hydrologic impacts from land use and LWD removal activities and develop a distributed hydrologic model calibrated for each sockeye tributary. Based on modeling results, prioritize actions needed to improve natural hydrologic processes in sockeye spawning streams.	H#15 (Q)	H#12 (Stab) H#13 (WQ)
RS#28	Tributary Spawners	Sediment	Within the sockeye spawning subbasins, quantitatively assess sediment production impacts from logging (gully creation, landslides), road building, LWD removal, and other land use activities. Develop program to eliminate and/or reduce land use-related sediment inputs to levels that create properly functioning conditions within these subbasins (this should be done in conjunction with RS#17-19).	H#11 (TSH) H#13 (WQ)	H#12 (Stab) H#16 (HP)
RS#29	Tributary Spawners	Riparian/Floodplain	Protect riparian forests and reestablish healthy riparian forests where degraded conditions exist within sockeye spawning subbasins.	H#11 (TSH) H#12 (Stab)	H#13 (WQ) H#16 (HP)
RS#30	Tributary Spawners	Riparian/Floodplain	Survey and eradicate non-native invasive plant species colonizing riparian areas.	H#11 (TSH) H#12 (Stab)	H#13 (WQ) H#16 (HP)
RS#31	Tributary Spawners	Riparian/Floodplain	Identify riparian/floodplain infrastructure; where feasible, develop alternatives to mitigate or remove infrastructure impairing riparian/floodplain processes.	H#11 (TSH) H#12 (Stab)	H#13 (WQ) H#16 (HP)

Recovery Strategy ID	Recovery Flow Chart (Population Segment Addressed)	Process, Input, or Condition	Description	Primary Hypotheses Addressed	Secondary Hypotheses Addressed
RS#32	Tributary Spawners	Riparian/Floodplain	Identify disconnected floodplain surfaces and add LWD to reconnect floodplains to channels to improve connectivity, sediment storage, water retention, and peak flow attenuation.	H#11 (TSH) H#12 (Stab)	H#13 (WQ) H#16 (HP)
RS33	Tributary Spawners	Biological	Increase the spatial distribution of tributary spawning sockeye by implementing the LOS HGMP.	NA	H#14 (Pred)
RS#33	Tributary Spawners	Habitat Condition	Throughout sockeye spawning streams where gravel deficient conditions exist, add LWD structures to trap and store spawning gravels. This must be done in conjunction with or after sediment and hydrologic processes are addressed.	H#11 (TSH)	NA